SECTION 6
PROGRAM COST ANALYSIS

This section provides an analysis of costs involved in implementing each of the four test regimes in the configurations described in Section 4. A detailed cost analysis model was developed that provides a framework for evaluating the program costs associated with each of the four test regimes. This life-cycle cost model categorizes cost elements into major submodels of research and development, acquisition and investment, and operations and maintenance. Results of exercising the model for each of the test regimes are then presented. Total program costs are enumerated for each test regime beginning with paragraph 6.3. Cost figures are subsequently analyzed on a submodel and parametric basis to reveal major areas of differences. Following cost value assignments, paragraph 6.5 provides an analysis of vehicle owner's cost incurred as a result of corrective maintenance. Concluding this section are the mathematical relationships used in developing the cost analysis model.

6.1 ECONOMICS OF EMISSION REDUCTION

The economic evaluation of any regulatory and mandatory program that is implemented and maintained for the public benefit involves far more than the application of statistical methods to the study of cost-related data. As mentioned previously in other sections of this report, vehicle emissions are a major contributor to air pollution, especially in terms of nitrogen oxidants and carbon monoxide. Each of these pollutants has its own characteristics and each community affected faces different meteorological, topographical, and economic conditions. As such, the effects and benefits derivable from an inspection program would not be equally applicable to the total populace. To justify the institution of a statewide testing concept, the benefits derived must be balanced against the costs incurred to achieve these advantages. The task, then, is to identify and quantify these costs.

6.2 COST ANALYSIS MODEL

Each of the four candidate test regimes under evaluation involves an extremely large number of fixed and variable cost items. Personnel wages, building costs, maintenance, and equipment and installation costs must all be systematically evaluated for each regime if the total cost of each of these four testing concepts is to be accurately assessed. To facilitate cost comparisons, both fixed and parametric, among the four candidate regimes, a linear life-cycle program cost model has been developed. This cost model identifies and quantifies the various program cost categories involved for each of the four regimes in their various configurations, and provides a convenient means for parametric and sensitivity analyses.

This cost model was designed to provide expected aggregate cost magnitudes for the various program areas throughout the desired program lifetime for each regime considered. Since the four regimes may vary widely both in cost and expected methods of implementation and administration, this cost model does not provide a cost accounting treatment of required program expenditures; it is simply a tool that allows cost items to be readily identified and analyzed.

The following sections describe the cost model, which was exercised for each of the four test regimes. This description is intended to present only the costing categories and concepts upon which the model is conceived. No numerical analyses are presented in this section.

6.2.1 General Description

The framework around which this cost analysis model has been designed is the concept of life-cycle cost. Life-cycle costing is a technique that assures that required resources are systematically considered, assists in the analytical process, facilitates data acquisition and mathematical computation, and indicates areas of critical resource requirements. The life-cycle cost (LCC) model used in subsequent analyses is composed of three major submodels corresponding to three major program phases: research and development, acquisition and investment, and operation and maintenance.

The research and development category includes all costs necessary to conceive, design, develop, and document a total program capable of satisfying the identified goals and objectives. For each of the test regimes evaluated, this cost category identifies and quantifies the expenditures necessary to finalize the concept to the point of implementation. Specific equipment, personnel, facilities, support management procedures, and all the other considerations are costed to assure complete coverage of resources. Deficiencies in equipment must be noted, and further research and development in technology must be funded either by industry, by the State, or by both. Such costs are part of this category.

The acquisition and investment category includes all the resources and costs incurred in the process of initial program implementation. The resource elements, facilities, and instrumentation and functional elements include indoctrination, initial training, and certification. This category includes those expenditures of a non-R&D and nonrecurring nature associated with the initial acquisition and start-up of the program.

The operation and maintenance category includes all those expenditures necessary to operate and maintain the inspection facility. Cost elements are expenses such as personnel wages and salaries, facilities upkeep, and sustaining or replacement training. This category includes all recurring expenditures for the total program.

Using the above three cost categories, the total program LCC for each test regime is calculated by manipulating the generalized, first-level-cost model delineated in equation (5).

$$LCC = \sum_{n=1}^{Y} \left\{ \left(C_{RD_n} + C_{INV_n} + Ke_n C_{OP_n} \right) \right\} \tag{5}$$

where:

LCC = total program cost for expected duration

C_{RD} = program research and development expenditures, in dollars

C_{INV} = facility acquisition and investment expenditures, in dollars

C_{OP} = operation and maintenance expenditures, in dollars

n = index of years in life-cycle duration

Ke_n = escalation factor applied for year n

Y = expected number of years in life cycle.

In the following paragraphs each of the major categories will be further defined by identifying the contributing cost elements as applicable to the test regimes and total program.

6.2.2 Program Research and Development Costs (C_{RD})

For each test regime, various research and development costs may be required before initial implementation. If present instrumentation cannot satisfy facility requirements, the cost to modify, upgrade, or develop the necessary equipments may be borne, in part, by the program. Additions or modifications to current methodology or technology must also be considered under this category, wherever essential advancements are necessary, before any selected implementation is instituted. After program implementation, any required R&D effort becomes part of program management costs as listed and described under annual operation and maintenance costs. A discussion of R&D costs applicable to all regimes is presented in Volume II, Section 10, of this report.

6.2.3 Facility Acquisition and Investment Costs (C_{INV})

As previously mentioned, this cost category will include those resources and functional costs that are related to initial acquisition and implementation. They are nonrecurring expenditures necessary to initiate the program and are differentiated from the research and development costs which were necessary prior to initial implementation. Described below are the general areas of interest.

6.2.3.1 Site Acquisition - Based on the physical locations selected for the inspection facilities, the land area required for station placement must be acquired, either purchased or leased, if not already owned. This will be a cost element regardless of who runs the program, State or private industry.

6.2.3.2 Facility Plans and Bids - All necessary site plans and construction drawings must be completed so that interested and qualified contractors may submit bids for consideration. The bids submitted must be evaluated, qualifications of contractors certified, and contracts drawn for the selected parties. Modifications to existing facilities would be handled somewhat differently; however, the cost elements would remain basically the same.

6.2.3.3 Facility Construction and Acceptance - New facilities must be constructed to comply with the facilities plans and drawings. In the case of older, established facilities, necessary modifications must be accomplished to accommodate any new equipments and space allocation requirements. Completed facilities are then inspected and certified for acceptance.

6.2.3.4 Equipment Acquisition and Installation - Equipments selected and recommended for the particular test regime must be purchased and installed. Acceptance tests must be conducted before the facility may be certified as an approved inspection facility. The test documentation would probably be supplied by the program management office. Additionally, it may be advisable for a team of qualified and trained technical inspectors to be available for guidance.

6.2.3.5 Personnel Indoctrination and Training - Depending on the test regime chosen for implementation, selected personnel may be required to receive the necessary program indoctrination and training to perform satisfactory vehicle inspection. Many of the test equipments and procedures may be unfamiliar to the affected technicians. Additionally, administrative, facility, and management personnel may be called upon to explain vehicle test program objectives and results. The training program may be developed and administered by the program office or by the facility owner using material provided by the program office. Identifiable cost elements would be the development of the training program, any equipments and documents essential to the training course, the required training of instructors if none are available, pay and travel allowances for instructors and students while receiving training, and apportioned costs for training facilities.

6.2.3.6 Station Qualification and Certification - After the facility is completely equipped and staffed, and prior to receiving the first vehicle to be inspected, the total facility must be qualified and certified. It was previously stated that equipments are accepted and certified after installation. These tests conducted now would be for the total system of equipments, personnel, procedures, and documentation to assure uniformity on a Statewide basis. Cost elements would be any special test procedures and certification duties and the facility personnel apportioned pay. Until the facility is certified, it is not operational.

The mathematical relationships which were used to quantify investment costs are presented in paragraph 6.6.

6.2.4 Operation and Maintenance Costs (C_{OP})

The functions and cost elements of an inspection facility are described below in terms of anticipated operating and maintenance activities. Personnel salaries, wages, and benefits would be the largest cost element required for an inspection facility annual expenditure. Sustaining personnel training and upgrading program may be instituted to assure continuing satisfactory operation. The maintenance of primary inspection equipment is of paramount importance, with secondary emphasis on supporting equipments, tools, and supplies. Administrative equipments and supplies also incur annual upkeep expenses. Additionally, the facility itself requires grounds and building maintenance. The functions performed by the program management office were previously identified in Section 2 of this report. In summary, these functions included vehicle scheduling, records administration, emission limits establishment and review, equipments requirement evaluation, and station qualification and certification. Other administrative functions common to any program management office are equally applicable.

6.2.4.1 Personnel Salaries, Wages, and Benefits - Based on the personnel requirements analysis conducted for each of the applicable test regime configurations, a complement of technical and administrative personnel is identified. The cost to staff the individual facilities would consist of all salaries, wages, and benefits required.

6.2.4.2 Personnel Training and Upgrading - New personnel added to the program subsequent to the initial start date may require indoctrination and training, depending on the test regime incorporated. In addition, current members of the inspection and administrative personnel staff would require periodic upgrading. The program management office may utilize the initial training facilities and materials to provide sustaining training, depending on the scope of the task. Anticipating that this function would not be of major proportions, perhaps the individual facility may incorporate program-directed training policies and procedures. The method of determining this training operation would be similar to that of determining the initial training phase.

6.2.4.3 Inspection-Oriented Equipments, Tools, and Supplies - The inspection-oriented equipments will require periodic preventive maintenance and some corrective maintenance activities. In most cases, various tools and supplies would be necessary to accomplish the tasks. Repair documents and replacement parts would be required in some instances to restore satisfactory operation of equipment. The expendable and consumable parts and supplies are part of operation and maintenance costs, whereas tools and documentation are part of initial investment.

6.2.4.4 Support-Oriented Equipments, Tools, and Supplies - These cost items are required to support the maintenance, calibration, and testing of the primary equipments and are not for items directly utilized during the emission analysis of vehicles. Included would be calibration gases, test equipments maintenance, and general-purpose tool replacements required for supporting activities.

6.2.4.5 Administrative Support Equipments and Supplies - There may be administrative support equipments included in the inspection facility to prepare inspection forms, record inspection data, and, where required, to record receipt of inspection fees. Incidental office supplies may also be required to complete the facility administrative office.

6.2.3.6 Inspection Facility Upkeep - Included in the cost of ownership would be the operations and maintenance expenditures for the facility itself. Grounds and building maintenance, all utilities required for operation and upkeep, and other incidental expenses such as property taxes and income taxes must be considered under this category.

6.2.3.7 Program Management and Administration Costs - Total management costs include salaries, wages, and benefits of administrative personnel; related office space and equipments; and clerical supplies. Depending on the type of management program implemented, there may be several levels of authority ranging from a department or agency level down to a regional district level. Each level of management would involve similar types of expenses. Any required surveillance or certification program would require supporting technical inspectors in addition to administrative personnel. The functional cost elements have been mentioned in Section 2 and also earlier in this section.

Prior to initial testing and inspection, vehicle scheduling must be conducted. Appropriate vehicle owners must be notified of the applicable inspection period and facility location. The proper forms and information pamphlets must be developed that would inform the public of program objectives and inspection policies and procedures. A program scheduling and monitoring concept must be developed and implemented to assure achieving the desired effects and benefits.

6.3 TEST REGIMES' COST ANALYSIS

This paragraph discusses the program costs of implementing and operating three separate conceptual configurations of each of the four test regimes. The three alternative configurations considered for each regime are:

a. A State-owned and operated system of inspection facilities. In costing this configuration, it is assumed that the State will acquire land for and will construct a network of vehicle emission test centers whose sole function will be vehicular inspection. No automotive service would be performed on site. Quoted costs include all those cost elements defined by the cost analysis model: site acquisition, facility construction, equipment acquisition, initial personnel training, and all other identified initial investment costs. Operating costs involve all identified recurring costs including such items as personnel wages and salaries, facility and equipment maintenance, and program administration. Profit and taxes in this configuration are assumed to be zero.

b. Privately owned and operated system of inspection facilities. This configuration assumes the State will select a private management concern to implement a program similar to that described in "a." Such a concern would oversee the selection of appropriate sites for the construction of a network of inspection facilities, which would not include on-site automotive service capabilities. These inspection facilities would be privately owned and managed subject to State-adopted regulations. A staff of State employees would review and monitor the operations of these private inspection facilities. Quoted costs for this configuration include all the cost elements delineated by the cost model and, in addition, the elements of profit and taxes, wherever applicable. To facilitate accurate comparison of the various program configurations, costs of automotive service are not included in this evaluation of program costs, but are reserved for a separate discussion.

c. State-licensed inspection facilities. This configuration assumes that existing privately owned facilities would perform vehicle emission inspections under license by the State. Automotive service could be performed on site. Individual licensees would purchase the prescribed test equipment complement and would perform the required emissions test for a fee assumed to consist solely of a labor charge. Quoted annual program costs include personnel costs and depreciation on purchased equipment, as well as profit. Taxes would not be applicable to the labor charge for inspection, and the equivalent property tax rate of 1 percent levied on the purchase price of equipment is considered sufficiently nominal to preclude discussion herein. For each regime in each of its configurations, costs are segregated into discussions of investment and operating costs.

The following analysis is based on the premise that a prescribed function, that of vehicle emission inspection, must be performed. Given that there are a variety of ways in which this function might be performed, cost analysis seeks to determine the total cost to perform the required function. Costs, therefore, are not expressed simply in terms of cost to the State or cost to the vehicle owner, but rather in terms of total cost required to accomplish the vehicle inspection task.

Each regime is analyzed initially on the basis of a twenty-year program life time. Facilities are depreciated over twenty years (straight-line method); all equipment is initially straight-line depreciated over ten years for uniformity of analysis among all four regimes.

For the case of State-licensed facilities, it is assumed that currently licensed class-A garages would be likely candidates for licenses. It is assumed for purposes of analysis that an equal number of existing class-A stations would participate in whatever regime was implemented. The number assumed participating is sufficient to accomplish testing of all cars in the State once annually. For operating costs in this configuration, current garage shop rates are used that account for labor, facilities, depreciation, profit, taxes, and other related cost items calculated separately for the first two configurations. Time-line functional-flow analyses previously performed for the case of private garages are used in the determination of the time required for an average private garage to perform the required inspection, and current garage practice is used in affixing the required fee.

Throughout the discussion that follows, California's 11 air basins are referred to numerically, in order of their decreasing estimated vehicle populations. Table 6-1 lists California's 11 air basins and the corresponding numeric reference for each of them.

Table 6-1. AIR BASIN NUMERICAL REFERENCES

Air Basin Reference	Air Basin
1	South Coast
2	San Francisco Bay Area
3	San Joaquin Valley
4	Sacramento Valley
5	San Diego
6	Southeast Desert
7	North Central Coast
8	South Central Coast
9	North Coast
10	Northeast Plateau
11	Great Basin Valley

6.3.1 Certificate of Compliance

6.3.1.1 State Owned and Operated Network of Inspection Facilities - In the State-owned, State-operated configuration, 387 identified inspection facilities consisting of an estimated 1366 lanes were evaluated by the life-cycle cost model. Based on the values assigned to the cost model variables that are presented later in paragraph 6.4, the total investment cost required to implement statewide inspection of all vehicles according to the Certificate of Compliance procedure delineated in Section 4, would be $30,263,000. This figure includes all investment cost items delineated, including construction of stationary facilities, purchase of all inspection equipment, training, etc. A graphic portrayal of the investment costs by air basin for this configuration of Certificate of Compliance is presented in

Figure 6-1. Considering a statewide program implemented as a whole, approximately 70 percent of all investment cost would be devoted to site acquisition and facility construction; approximately 26 percent would be devoted to inspection and related support equipment acquisition, and the remainder would be devoted to all other investment costs, including initial training and station qualification and certification. Investment costs for this configuration are presented in Table 6-2. In this case, as for all the four test regimes considered, a parametric analysis was performed for the most significant cost elements. Equipment acquisition, site acquisition, and facility construction cost components were allowed to vary ±20 percent to determine the resultant effect on investment cost. These variations are presented as endpoints of the expected value variation of the various aggregate costs identified.

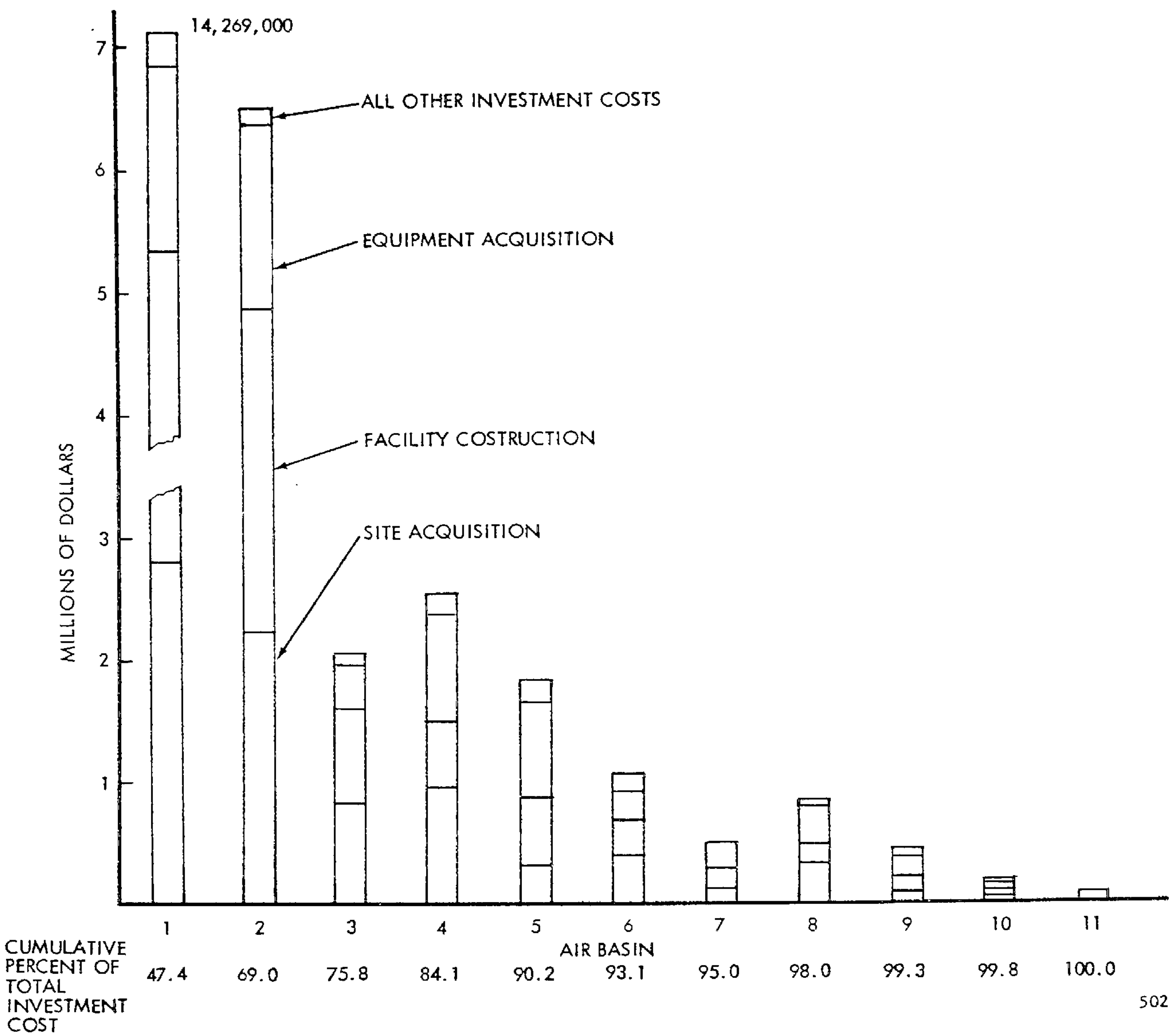

Figure 6-1. INVESTMENT COST BY AIR BASIN CERTIFICATE OF COMPLIANCE

Table 6-2. INVESTMENT COSTS - CERTIFICATE OF COMPLIANCE NETWORK OF NEW FACILITIES (THOUSANDS OF DOLLARS)

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Site Acquisition	5,629	2,030	765	995	288	400	80	288	104	30	0
Facility Construction	5,008	2,641	725	541	643	252	147	171	109	19	0
Stationary Site Inspection Equipment	3,145	1,560	440	335	430	165	95	115	70	10	0
Mobile Site Inspection Equipment	0	0	0	480	310	150	170	240	90	40	10
Training Costs	310	158	47	58	59	16	17	24	11	3	0.5
Facility Plans and Bids	15	-	-	-	-	-	-	-	-	-	-
Qualification and Certification											
Salaries of Field Personnel Including Travel Allowance and Fringe	27	26	20	23	22	25	14	14	14	14	0
Program Administrative Costs	135	99	57	92	57	31	31	31	31	31	31
Total: Per Basin	14,269	6,514	2,054	2,524	1,809	1,039	554	883	429	147	41.5
Parametric High	17,122	7,803	2,462	3,023	2,072	1,244	663	1,057	514	176	49
Parametric Low	11,471	5,228	1,649	2,025	1,388	833	444	708	334	118	33

ALL BASINS: Total - 30,263; Parametric High - 36,185; Parametric Low - 24,231

Operating costs for this configuration of Certificate of Compliance for 1972 are presented in Figure 6-2 and Table 6-3. Approximately 85 percent of the total program's annual operating cost would be devoted to salaries, wages, and benefits to inspection station administrative and station inspection personnel. Program administrative personnel costs account for approximately 5 percent of total program operating costs, and all maintenance costs represent approximately 5 percent. As stated previously, all operating costs are assumed to be subject to a 5 percent annual rate of increase for all modes of implementation of each regime.

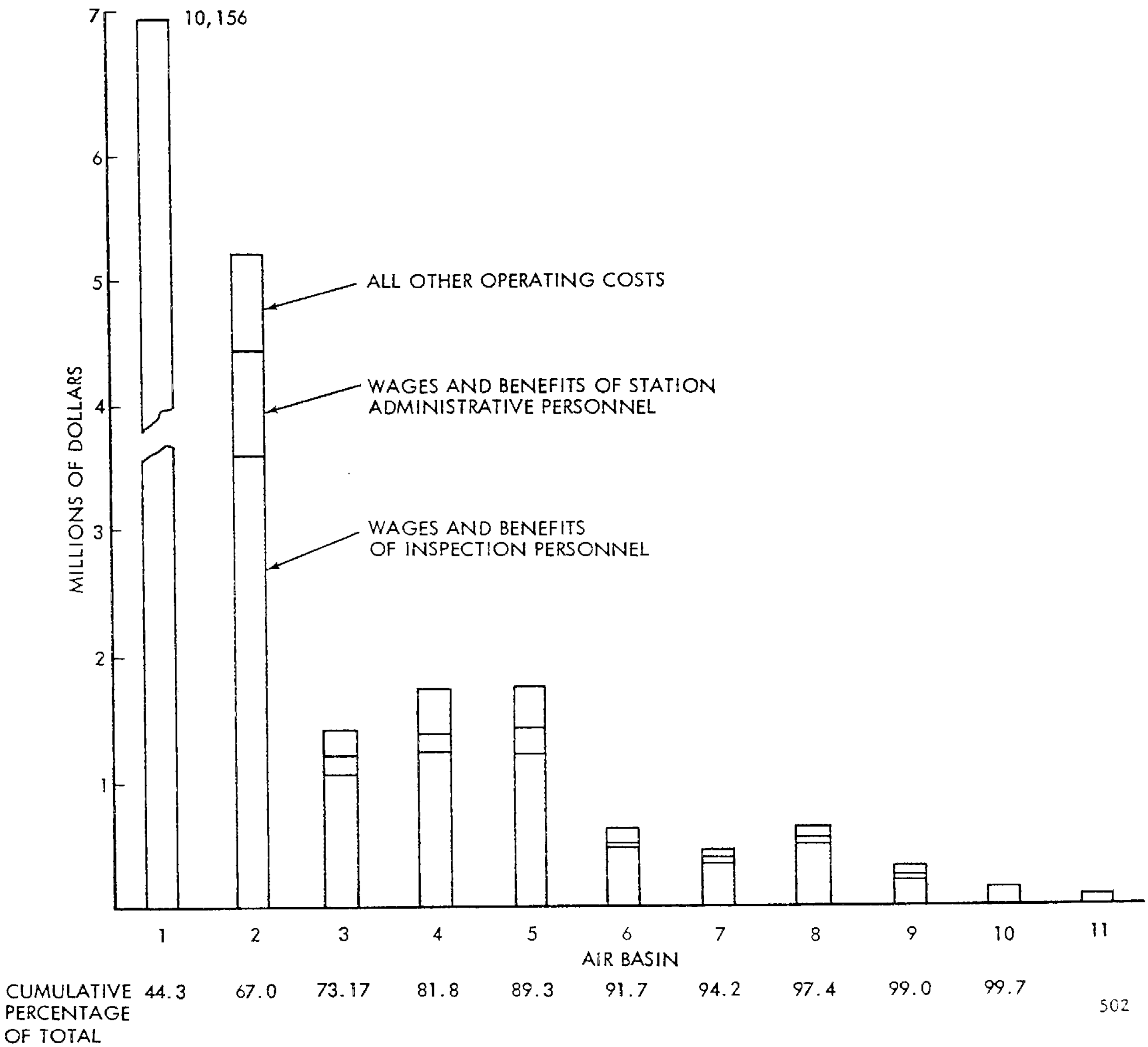

Figure 6-2. OPERATING COST BY AIR BASIN FOR 1972 - STATE OWNED AND OPERATED NETWORK OF INSPECTION FACILITIES

Table 6-3. CERTIFICATE OF COMPLIANCE OPERATING COSTS FOR 1972 (THOUSANDS OF DOLLARS)
STATEWIDE SYSTEM OF STATE OWNED AND OPERATED INSPECTION FACILITIES

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Salaries of Stationary Facility Inspection Personnel	7,283	3,612	1,019	775	995	382	220	266	162	23	0
Salaries of Mobile Station Inspection Personnel	0	0	0	555	358	200	197	278	104	46	11
Salaries of Station Administrative Personnel	1,444	795	113	106	201	41	25	44	13	0	0
Equipment Maintenance	314	156	44	81	74	16	26	35	16	5	1
Equipment Depreciation (S/L 10 Years)	314	156	44	81	74	16	26	35	16	5	1
Facility Maintenance	250	132	36	27	32	12	7	8	5	2	0
Inspection Facility Depreciation (S/L 20 Years)	250	132	36	27	32	12	7	8	5	2	0
Salaries of Program Administrative Personnel	269	200	107	116	107	50	50	50	50	50	50
All Other Program Administrative Operating Costs	32	22	16	41	15	10	10	10	10	10	10
Total: Per Basin	10,156	5,205	1,415	1,809	1,888	739	568	734	381	142	73
Parametric High	12,167	6,236	1,695	2,167	2,262	885	680	879	456	170	87
Parametric Low	8,237	4,221	1,148	1,467	1,531	599	461	595	309	115	71
ALL BASINS: Total - 23,110; Parametric High - 27,684; Parametric Low - 18,754											

6.3.1.2 Contractor Owned and Operated, State-Regulated Network of Inspection Facilities - This configuration assumes a private concern will perform the same tasks as would the state in selecting sites for, and constructing a network of vehicle emission inspection stations. Assuming the state would assist the selected concern in site acquisition in exercising powers of eminent domain where required, there would be no identifiable aggregate cost differences from those investment costs identified in the previous configuration, since fair market prices were assumed for all purchases. It is anticipated that the State would assume a regulatory role during the preoperational program investment period, and it is also assumed that the same regulatory staff would be maintained during the operational lifetime of the program. It is this administrative cost, profit, and taxes that differentiate this implementation from the State-owned and State-operated configuration in terms of operating costs. Clearly, it is recurring operating costs that form the largest portion of the program outlined under the State-owned, State-operated configuration. An annual sum of $23,110,000, escalating annually by 5 percent, plus equipment replacement, when required, must be expended for operating costs. If the state were to adequately monitor the performance of a statewide inspection program of vehicle inspection, it is anticipated that a regulatory agency, consisting of positions varying from station inspector to regional director to state director, would be required. It is here that a duplication of effort appears to exist, for in this configuration, the State, in addition to the private management concern, must inspect and monitor inspection station performance and overall program performance. Considering the cost of the State administrative staff involved, it is anticipated that a reasonable estimate of the cost of such a staff should not exceed 2 percent of total program operating costs. In the case of Certificate of Compliance as described in paragraph 6.3.1.1, this would amount to a 1972 expenditure of approximately $460,000. This cost would be subject to escalation, as would be all other operating costs.

Program operating costs in addition to this annual administrative cost required to support auxiliary state supervision, and that are in addition to those discussed in paragraph 6.3.1.1, and that would be expected to accrue, are those of profit and taxes. Assuming an annual operating profit of 25 percent, a private operator would recover his initial investment cost in approximately six years. Taxes involve a nominal figure since it was assumed that only a labor inspection fee would be charged to the public. Thus, it is property tax and equipment tax that would be paid. At 8 percent of assessed value (25% of market value), approximately $400,000 would be realized and could be used to support the State regulatory agency. This cost, however, would be paid from profit, which would be paid for by the public. Once again remember, we are interested in total cost involved. Operating costs, assuming a 25-percent profit margin, are presented in Table 6-4 for 1972 for the privately owned and operated configuration of Certificate of Compliance.

6.3.1.3 State-Licensed Inspection Facilities - In this configuration it is assumed that existing automotive facilities such as automobile dealerships, independent garages, and service stations would purchase required inspection equipment and perform the inspection for a labor charge. Again, although automotive service might be performed on-site, such costs are not considered in this discussion. As shown by functional flow time-line analyses performed earlier, personnel will not perform inspections as rapidly as they would in high-throughput assembly-line type inspection lanes.

Of the currently existing Class-A licensed stations (approximately 7000 statewide) assume for purposes of discussion that approximately 5000 of these stations would participate as licensed vehicle emission test centers.

Table 6-4. 1972 OPERATING COST OF CERTIFICATE OF COMPLIANCE; PRIVATELY OWNED, PRIVATELY OPERATED, STATE-REGULATED SYSTEM

Air Basin	Total Operating Cost for 1972
1	$12,898,000
2	6,610,000
3	1,797,000
4	2,297,000
5	2,398,000
6	939,000
7	721,000
8	932,000
9	484,000
10	180,000
11	93,000
Total	$29,349,000

Equipment investment costs would be approximately $24,000,000, or approximately four times that of the State owned and operated configuration, as approximately four times the number of lanes of equipment would be required, minus required equipment already possessed by class-A garages. Training costs would approximate $2,800,000, as approximately four times the number of lane personnel would require training. Approximately $800,000 would be required for salaries of qualification and certification field personnel, assuming the same time would be required to inspect and certify each inspection lane. A total of $28,600,000 would therefore be required for investment costs in this implementation configuration. Based on the time-line functional flow analysis for private garages in the Certificate of Compliance regime, an estimated time of 45 minutes would be required to perform one test. At current shop rates ($12/hr), one would expect an inspection fee of $9/car, or approximately 90 million dollars in operating costs for 1972 in addition to the 2 percent State administration cost, identified previously, of $18 million, for a total expected 1972 operating cost of $108 million. The specific values assigned to cost model variables for Certificates of Compliance are presented in paragraph 6.4.

6.3.2 Idle Test

6.3.2.1 State Owned and Operated - For a State owned and operated system of idle test vehicle emission inspection stations in the configuration described in Section 4, as prescribed by the station simulation model, an initial investment cost of $12,084,000 for all air basins in the State is anticipated. Once again, as Table 6-5 and Figure 6-3 indicate, the major portion of this expenditure, approximately 59 percent, is allotted for land acquisition and facility construction. Equipment acquisition costs approximate one-third of total investment expenditures. As before, nearly 90 percent of the total investment cost is expended in the first five largest air basins. Note the consistent and relatively large percentage of the total investment cost represented by equipment acquisition costs, which increases

Table 6-5. IDLE TEST INVESTMENT COSTS NETWORK OF NEW FACILITIES (THOUSANDS OF DOLLARS)

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Site Acquisition	2,159	1,323	236	200	297	127	94	100	30	0	0
Facility Construction	1,262	654	179	103	157	81	43	53	19	0	0
Stationary Site Inspection Equipment	1,550	750	200	100	210	100	50	60	20	0	0
Mobile Site Inspection Equipment	0	0	325	225	50	100	75	50	100	50	25
Equipment Installation	32	15	4	2	2	1	1	1	0	0	0
Training Costs	44	21	9	5	6	4	2	2	2	1	1
Facility Plans and Bids	15	-	-	-	-	-	-	-	-	-	-
Qualification and Certification											
Salaries of Field Personnel Including Travel Allowance and Fringe	27	26	20	23	22	25	14	14	7	0	0
Program Administrative Costs	133	97	56	92	56	29	29	29	29	16	13
Total: Per Basin	5,222	2,886	1,029	750	800	467	308	309	207	67	39
Parametric High	6,256	3,457	1,233	899	958	559	369	370	248	80	47
Parametric Low	4,182	2,312	824	601	641	374	247	248	166	54	31
ALL BASINS: Total - 12,084; Parametric High - 14,476; Parametric Low - 9,680											

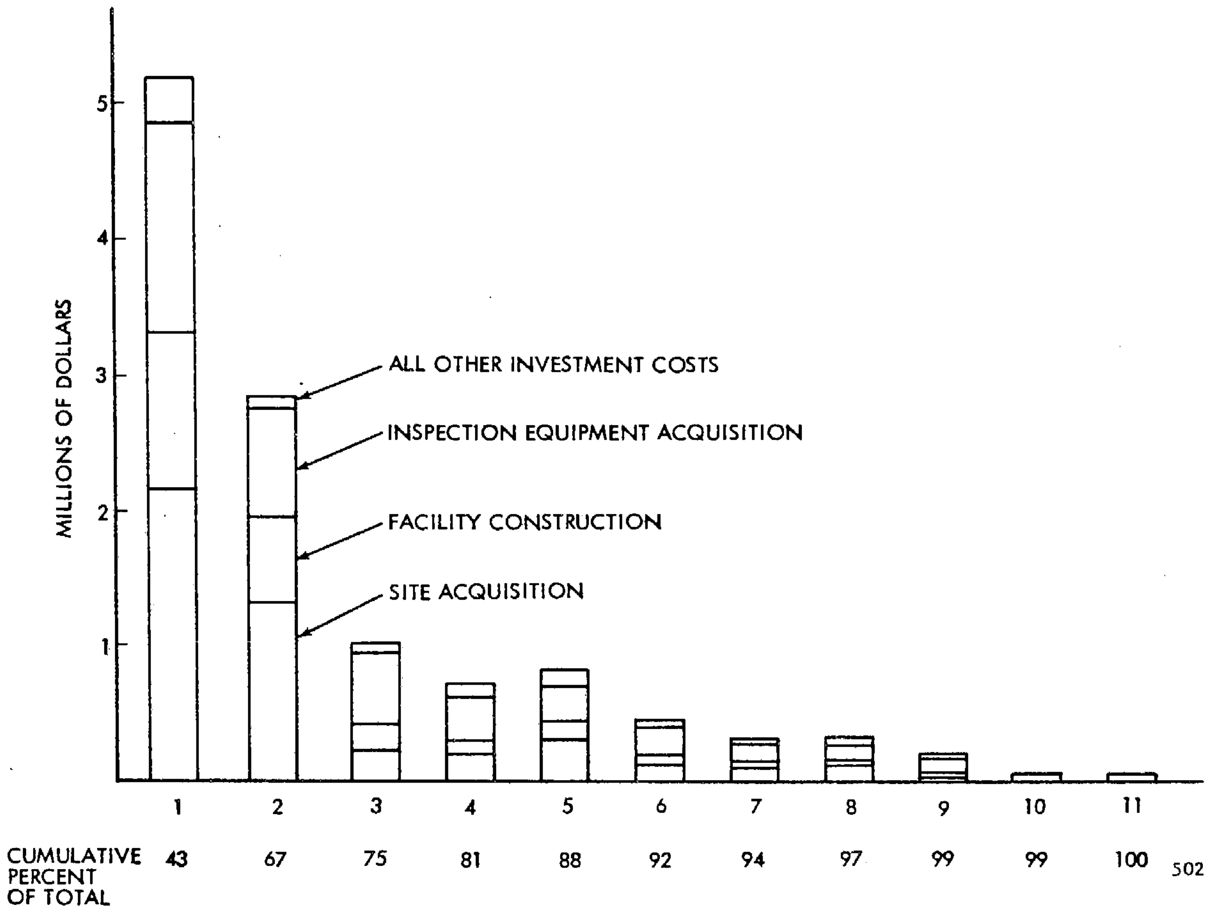

Figure 6-3. INVESTMENT COSTS IDLE TEST STATEWIDE NETWORK OF NEW FACILITIES

consistently, particularly for the smaller air basins, reflecting not only a relatively high vehicle throughput per facility, but also the increasing percentage of mobile facilities relegated to the smaller air basins (6-11). Results of parametric variation in equipment, land, and building costs are summarized in Table 6-5.

Turning to operating costs, Table 6-6 and Figure 6-4, a total of $9,576,000 is the total projected 1972 operating cost, assuming equipment is depreciated over a ten-year period and facilities are depreciated over a projected twenty-year program lifetime. Both are straight-line depreciations. As one would expect, inspection station personnel salaries once again represent the largest proportion, 70 percent, of all operating expenditures. Salaries of program administrative personnel represent an average of 8 percent of operating costs for the first two air basins and increase proportionately with decreasing basin size, to 57 percent in air basin 11. This is reflective of the minimum administrative staff that was assigned to any given air basin. Again, parametric costing results are summarized in Table 6-5.

6.3.2.2 Privately Owned and Operated, State-Regulated System - Considering a privately owned version, this idle test configuration, if the same rationale for assigning State supervisory staffing is applied in this case as previously, a

Table 6-6. OPERATING COSTS FOR 1972 (THOUSANDS OF DOLLARS)
STATEWIDE NETWORK OF STATE OWNED AND OPERATED
INSPECTION FACILITIES

IDLE TEST

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Salaries of Stationary Facility Inspection Personnel	2,956	1,424	403	232	401	199	107	125	46	0	0
Salaries of Mobile Facility Inspection Personnel	0	0	241	167	37	74	56	37	74	37	19
Salaries of Station Administrative Personnel	356	183	32	0	46	7	0	7	0	0	0
Equipment Maintenance	155	75	53	33	26	20	13	11	12	5	3
Equipment Depreciation (S/L 10 Years)	155	75	53	33	26	20	13	11	12	5	3
Inspection Facility Maintenance	63	33	9	5	8	4	2	3	1	0	0
Inspection Facility Depreciation (S/L 20 Years)	63	33	9	5	8	4	2	3	1	0	0
Salaries of Program Administrative Personnel	264	195	103	114	103	46	46	46	46	46	46
All Other Program Administrative Operating Costs	32	22	16	42	15	10	10	10	10	10	10
Total: Per Basin	4,044	2,040	919	631	670	384	249	253	202	103	81
Parametric High	4,845	2,444	1,101	756	803	460	209	303	242	123	97
Parametric Low	3,239	1,634	881	505	537	308	199	202	162	83	65
ALL BASINS: Total - 9,576; Parametric High - 11,472; Parametric Low - 7,815											

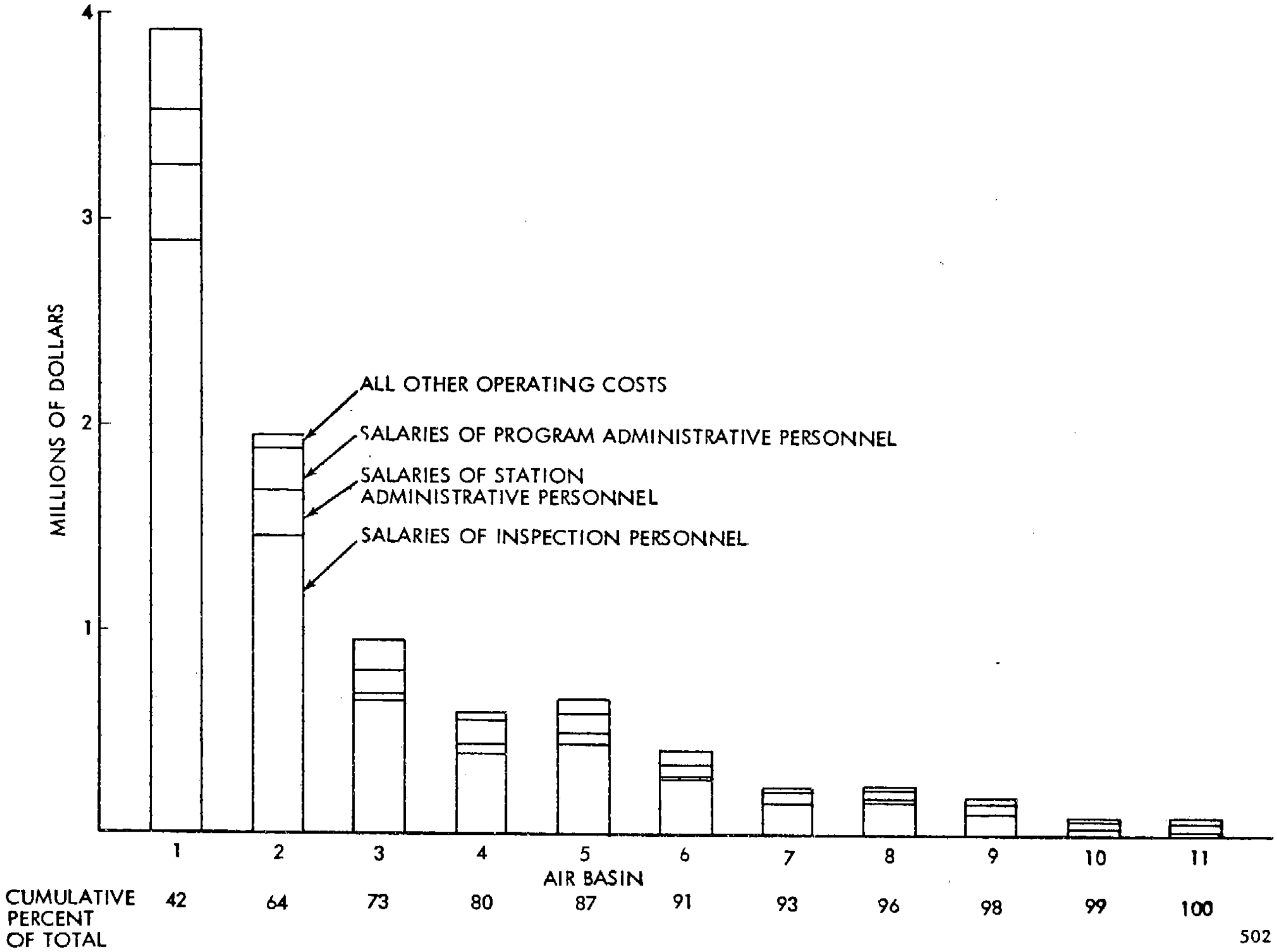

Figure 6-4. IDLE TEST OPERATING COSTS FOR 1972 STATEWIDE NETWORK OF NEW FACILITIES

2-percent administrative burden of $191,000 would be expected in 1972. If an operating profit of 25 percent is assumed, initial investment would be recovered in approximately five and one-half years. Operating costs by air basin for a privately owned network of idle test emission inspection centers, assuming a 25 percent operating profit, are presented in Table 6-7.

6.3.2.3 State Licensed Inspection Facilities - Based on known labor rates and calculated test times, as for private service facilities, an expected value for the fee charged by a private garage or dealer service center or service station to perform an idle test without accompanying service would be calculated as follows: 30 minutes test time by $12/hour shop rate = $6. Initial investment cost, assuming as before, approximately 5000 participating lanes, would be $50,000,000, or roughly, 17 times the previous configuration, as approximately 17 times as many equipment sets would be required to achieve required annual throughput. This figure includes only the cost of inspection-related equipment and assumes no site acquisition or facility construction costs. No portion of this cost has been allocated for the repair function.

Table 6-7. COST PER BASIN (1972)

Air Basin	Total Operating Cost for 1972 ($)
1	5,135,000
2	2,591,000
3	1,167,000
4	801,000
5	851,000
6	488,000
7	316,000
8	321,000
9	257,000
10	131,000
11	103,000
Total	12,161,000

Training costs would also be expected to increase approximately 16 times, assuming no more men per lane than prescribed in the test configuration would require training. Expected training costs would be $1,649,900. In the area of Qualification and Certification, approximately $2,626,000 would be required in certification field personnel salaries, assuming the mean time required to certify a lane in an existing facility is equivalent to that of a lane in a private facility. In reality, one should expect larger times per lane if interstation travel time is accounted for. Total expected investment cost is $55,200,000.

Operating costs for inspecting 10 million cars in 1972 would be $60,000,000 in inspection fees plus $1,200,000 (2 percent) in State administration costs. Total operating cost is $61,200,000.

Parametric analysis indicates the upper and lower bounds on these costs to be $14,189,000 and $9,463,000, respectively. The values assigned to cost model variables for idle test regime are discussed in paragraph 6.3.6.

6.3.3 Key Mode

6.3.3.1 State Owned and Operated System - To initiate a statewide network of key mode vehicle emission inspection facilities according to the design requirements established in Section 4 of this report, it is estimated that a total initial investment cost of $19,830,000 would be required. Investment costs by air basin for the State owned and operated key mode configuration are presented in Figure 6-5 and Table 6-8.

Facility site acquisition and facility construction costs once again dominate the investment category at approximately 63 percent of the total investment requirement. Inspection equipment acquisition cost accounts for 29 percent of total projected investment expenditures. Once again, approximately 90 percent of the total program investment cost is allocated to the first five largest air basins. Summary results of parametric analysis are presented in Table 6-8.

Table 6-8. KEY MODE INVESTMENT COSTS NETWORK OF NEW FACILITIES
(THOUSANDS OF DOLLARS)

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Site Acquisition	3,915	1,897	328	361	420	119	104	134	37	0	0
Facility Construction	2,497	1,292	343	277	314	176	77	100	54	0	0
Stationary Site Inspection Equipment	2,522	1,248	325	247	338	182	78	104	52	0	0
Mobile Site Inspection Equipment	0	0	144	144	0	72	72	36	72	36	18
Equipment Installation	194	192	50	38	52	28	12	16	8	0	0
Training Costs	80	39	13	11	10	7	4	4	3	1	1
Facility Plans and Bids	20	-	-	-	-	-	-	-	-	-	-
Qualification and Certification	-	-	-	-	-	-	-	-	-	-	-
Salaries of Field Personnel Including Travel Allowance and Fringe	42	41	35	38	37	40	30	30	30	0	0
Program Administrative Costs	135	100	59	92	57	31	31	31	31	11	11
Total: Per Basin	9,405	4,809	1,297	1,208	1,228	655	408	455	287	48	30
Parametric High	11,286	5,771	1,556	1,450	1,474	786	490	546	344	58	35
Parametric Low	7,524	3,847	1,038	966	982	524	326	364	230	38	23
ALL BASINS: Total - 19,830; Parametric High - 23,796; Parametric Low - 15,862											

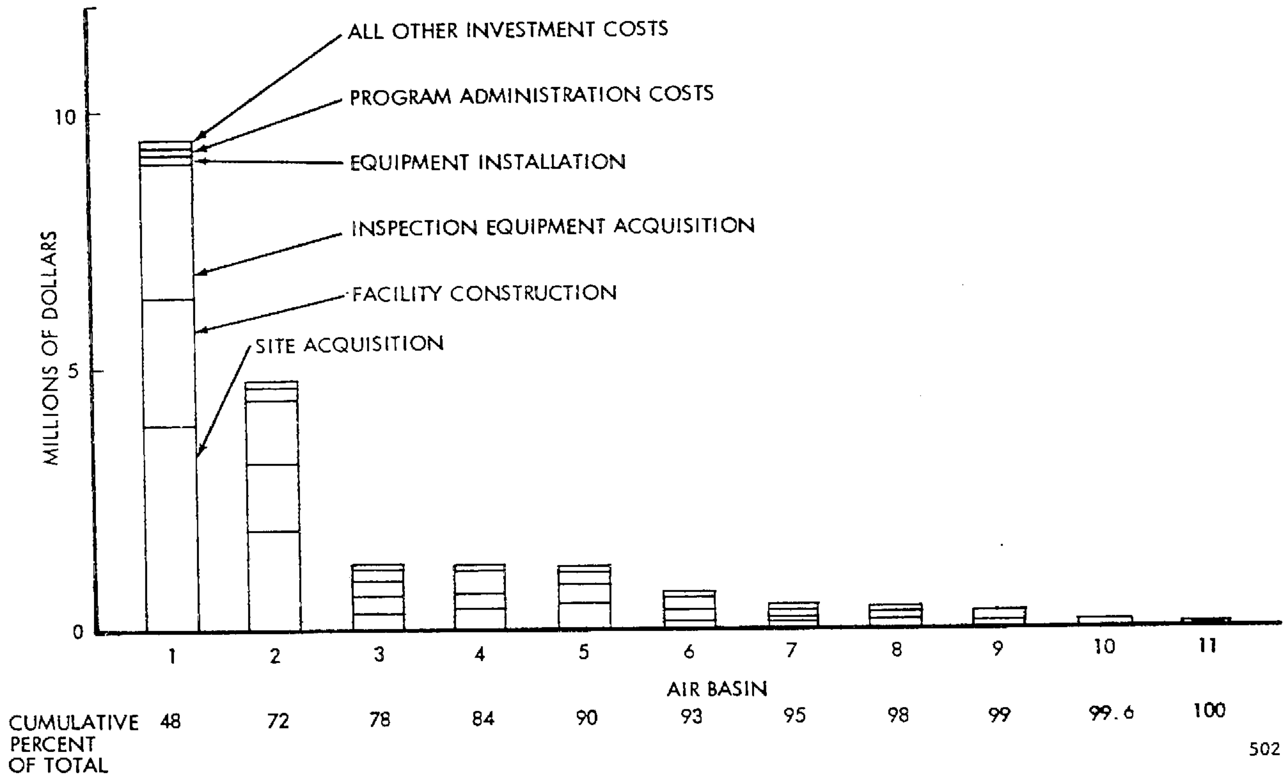

Figure 6-5. INVESTMENT COSTS BY AIR BASIN KEY MODE TEST STATEWIDE NETWORK OF NEW FACILITIES

Operating costs for 1972 for the State-owned, State-operated configuration are presented in Figure 6-6 and Table 6-9. Total 1972 operating cost, including facility depreciation (20 year, straight-line method) and equipment depreciation (10 year, straight-line method) is estimated at $10,476,000, of which approximately 59 percent is salaries paid to inspection lane personnel. Station administrative salaries represent about 9 percent of total operating cost, while program administrative personnel account for a full 11 percent of the total operating cost. Here again, the administrative burden placed on the less densely populated air basins becomes evident, with program administrative personnel salary costs accounting for 64 percent of all operating funds programmed for air basin 11, Great Basin Valley Air Basin.

6.3.3.2 Privately Owned and Operated System - Using the same analysis format applied to the previous two test regimes, 2 percent of the operating cost will be allotted to support annually the State administrative personnel required to supervise and monitor program operation. Allowance for operating profit of 25 percent produces a total 1972 operating cost of $13,305,000. Table 6-10 presents estimated operating costs by air basin.

The values assigned to cost model variables for the Key Mode test regime are discussed in paragraph 6.4.

Table 6-9. OPERATING COSTS FOR 1972 (THOUSANDS OF DOLLARS)
STATEWIDE NETWORK OF STATE OWNED AND OPERATED
INSPECTION FACILITIES

KEY MODE TEST

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Salaries of Stationary Facility Inspection Personnel	3,034	1,501	391	297	407	219	94	125	63	0	0
Salaries of Mobile Facility Inspection Personnel	0	0	125	125	0	63	63	31	63	31	16
Salaries of Station Administrative Personnel	530	268	58	37	55	21	0	12	0	0	0
Equipment Maintenance	233	115	41	34	31	22	13	12	10	3	1
Equipment Depreciation (S/L 10 Years)	233	115	41	34	31	22	13	12	10	3	1
Inspection Facility Maintenance	125	65	17	14	16	9	4	5	3	0	0
Inspection Facility Depreciation (S/L 20 Years)	125	65	17	14	16	9	4	5	3	0	0
Salaries of Program Administrative Personnel	271	201	107	117	107	50	50	50	50	50	50
All Other Administrative Operating Costs	32	32	16	42	16	10	10	10	10	10	10
Total: Per Basin	4,583	2,362	813	714	679	425	251	262	212	97	78
Parametric High	5,490	2,830	974	855	813	509	301	314	254	116	93
Parametric Low	3,671	1,891	651	572	544	340	201	210	170	78	62

ALL BASINS: Total - 10,476; Parametric High - 12,549; Parametric Low - 8,390

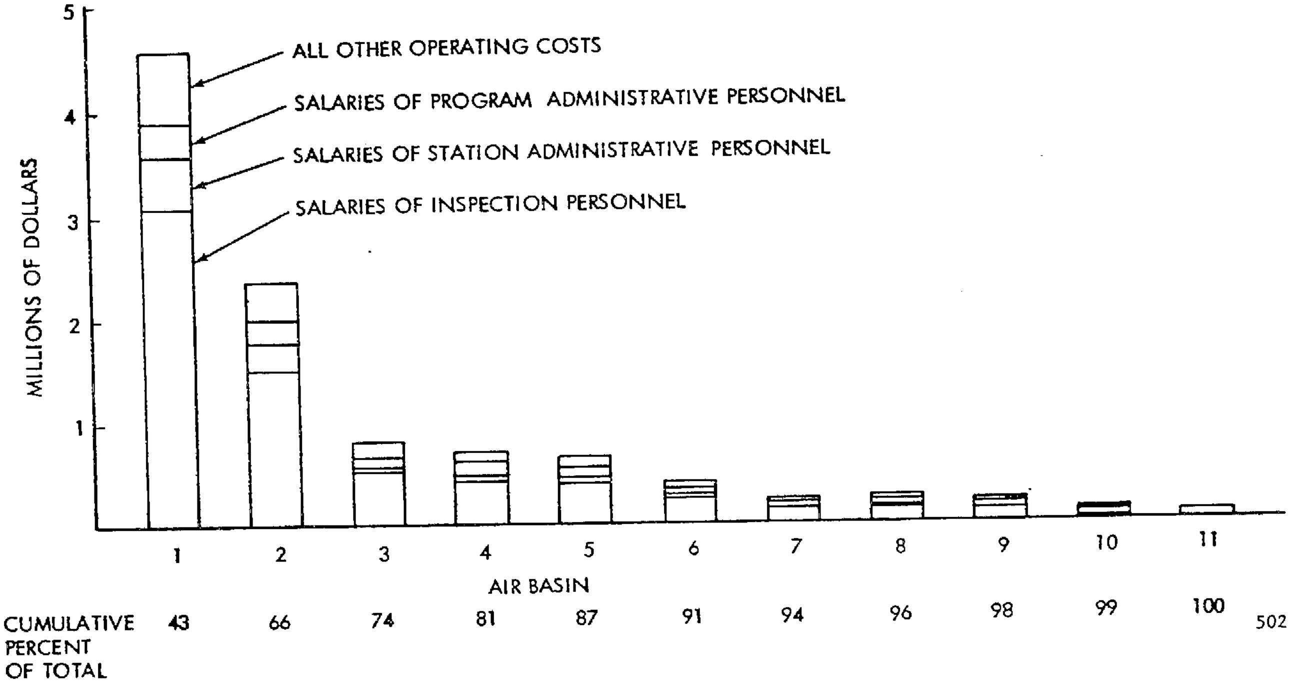

Figure 6-6. OPERATING COSTS FOR 1972 KEY MODE TEST STATEWIDE NETWORK OF NEW FACILITIES

Table 6-10. OPERATING COSTS FOR 1972 - PRIVATELY OWNED AND OPERATED NETWORK OF KEY MODE FACILITIES

Air Basin	Operating Cost for 1972
1	$5,820,000
2	3,000,000
3	1,033,000
4	907,000
5	862,000
6	540,000
7	319,000
8	333,000
9	269,000
10	123,000
11	99,000
Total	$13,305,000

The values assigned to cost model variables for the Key Mode test regime are discussed in paragraph 6.4.

6.3.3.3 <u>State Licensed Inspection Facilities</u> - Following the same analysis procedures indicated for the previous regimes, an expected value of the inspection fee per vehicle that would be charged by existing facilities to perform the key mode inspection is calculated as follows:

Test time = 30 min x $12/hr shop rate = $6 inspection fee.

If all cars in the state were tested at this rate, an operating cost of $60 million would be expected. With the usual 2 percent administrative allotment, a total 1972 operating cost of $61,200,000 would be expected. Equipment investment costs would be expected, assuming again 5,000 participating lanes to be approximately 12 times the 398 lanes of the State owned and operated configuration, or a total of $61,500,000.

Initial training requirements, based upon an assumed proportional increase in participating lane personnel, are estimated at $2,076,000. Field cost involved in qualification and certification, again expected to be proportional to lane and station requirements, would require $3,880,000. Total investment cost required would be $67,456,000.

The values assigned to cost model variables for the diagnostic regime are discussed in paragraph 6.4.

6.3.4 Diagnostic Test

6.3.4.1 State Owned, State Operated Network of Diagnostic Facilities - The total expected investment cost required to implement a statewide system of diagnostic test centers of the types and number described in Section 4 is estimated to be $88,776,000. Refer to Table 6-11 and Figure 6-7 to supplement the following discussion. In the case of this test regime, approximately 72 percent of the total investment cost is allocated for site acquisition and facility construction costs; facility construction alone accounts for approximately 30 to 40 percent, even in those air basins with a considerable number of mobile lanes allotted. Inspection equipment acquisition costs account for 26 percent of the total, leaving approximately 3 percent allotted to all other investment costs including equipment installation, training, and certification. This situation reflects the large land and facility requirements for diagnostic test implementation. Once again, approximately 90 percent of investment expenditures are allotted to the first five air basins. Training costs, although a large consideration in program design and implementation, represent approximately 1 percent of total investment cost allocation. Results of parametric analysis are presented in Table 6-11.

Operating costs for full implementation of the State-owned, State-operated configuration are presented in Figure 6-8 and Table 6-12. Personnel costs once again predominate, accounting for 66 percent of the projected 1972 operating cost in terms of inspection personnel alone. A total of 16.9 percent is allotted to station administrative personnel while program administrative salaries amount to 3.7 percent of total operating expense. Salaries paid to personnel account for 86.1 percent of operating cost. Facility maintenance and depreciation total 12 percent of projected 1972 operating costs for full program implementation. Parametric analysis yielded results summarized in Table 6-12.

6.3.4.2 Privately Owned and Operated State-Regulated Network of Diagnostic Emission Test Facilities - As in the previous cases, an administrative cost of 2 percent of annual operating cost is allotted for State supervision. A total of $612,000 would be required. With 25 percent profit margin allowed, expected operating costs by air basin for 1972 for this configuration are presented in Table 6-13.

Table 6-11. DIAGNOSTIC INVESTMENT COSTS NETWORK OF NEW FACILITIES (THOUSANDS OF DOLLARS)

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Site Acquisition	12,524	8,571	1,932	2,011	946	539	617	683	191	50	33
Facility Construction	16,764	8,714	2,595	1,995	2,280	1,140	562	647	375	68	68
Stationary Site Inspection Equipment	10,323	4,700	1,590	1,059	1,472	673	395	547	231	35	35
Mobile Site Inspection Equipment	0	0	0	624	130	208	208	130	260	78	52
Equipment Installation	242	122	35	26	34	17	8	10	5	1	1
Training Costs	519	257	76	96	81	49	30	29	27	7	5
Facility Plans and Bids	25	-	-	-	-	-	-	-	-	-	-
Qualification and Certification											
Salaries of Field Personnel Including Travel Allowance and Fringe	87	47	44	44	43	45	30	28	15	9	4
Program Administrative Costs	145	107	61	92	61	31	31	30	27	20	18
Total: Per Basin	40,629	22,518	6,333	5,947	5,047	2,702	1,881	2,104	1,131	268	216
Parametric High	48,754	27,022	7,600	7,136	6,056	3,242	2,257	2,525	1,357	322	259
Parametric Low	32,503	18,014	5,066	4,758	4,038	2,162	1,505	1,683	905	214	173
ALL BASINS: Total - 88,776; Parametric High - 106,530; Parametric Low - 71,021											

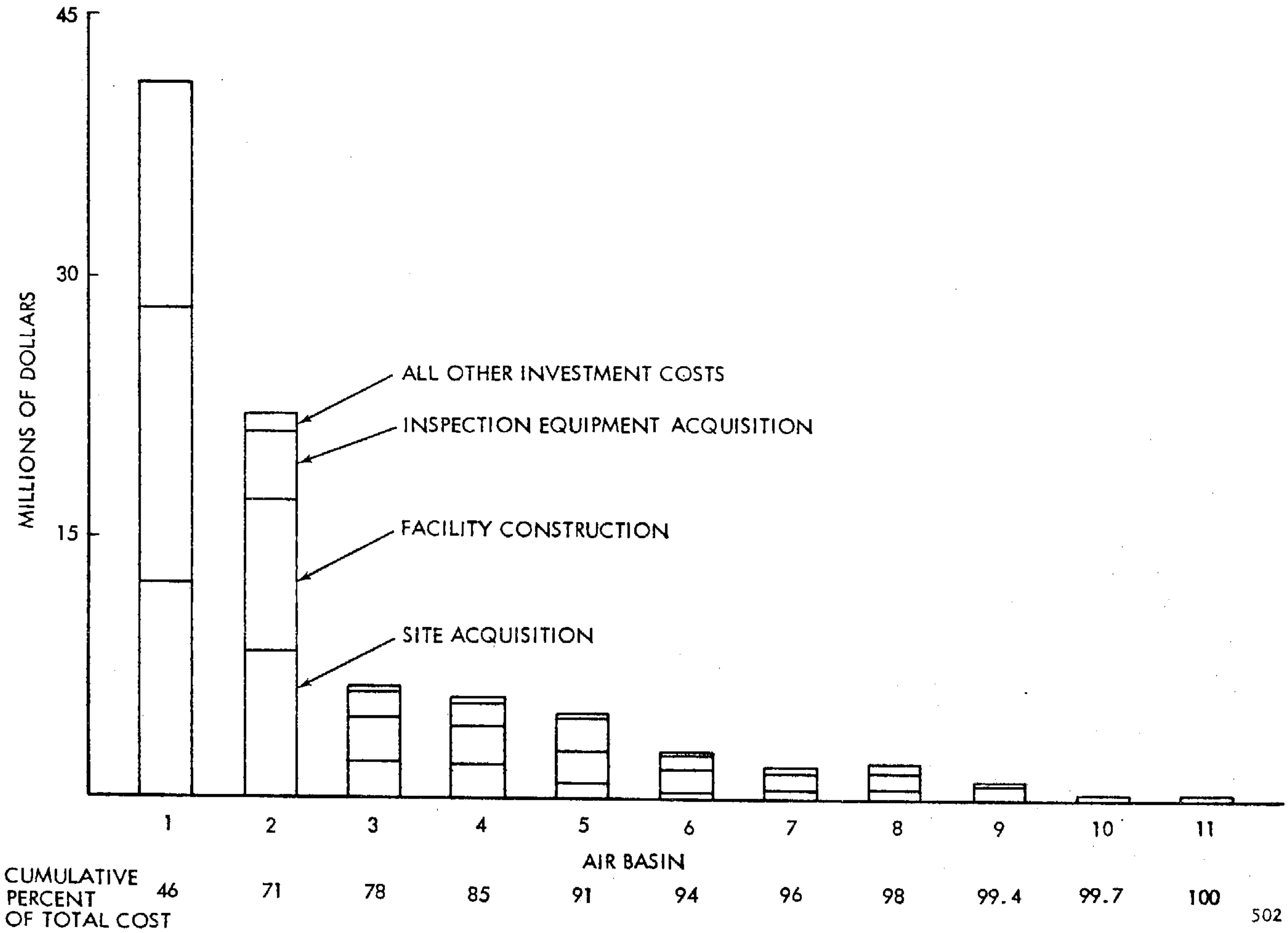

Figure 6-7. INVESTMENT COST BY AIR BASIN DIAGNOSTIC TEST STATEWIDE NETWORK OF NEW FACILITIES

6.3.4.3 State Licensed Emission Inspection Facilities - Based on vehicle throughput analysis and current practices of private automotive service centers, assuming a sufficient number of qualified personnel could be obtained, an anticipated fee of $12 would be charged per vehicle, calculated as follows:

60 minutes test time x $12/hr shop rate = $12

Such a fee would yield a 1972 operating cost contribution of $120,000,000. Administrative cost (2 percent) would be $2,400,000 for a total 1972 operating cost of $122,400,000. An approximate equipment acquisition investment cost of $140,000,000 would be expected for the 5,000 lanes, assumed for purposes of uniform cost analysis, that may choose to participate, based on the increased number of lanes from 784 that are indicated in the State owned and operated configuration.

Assuming 5000 lanes participating, initial training fees would require a proportionate increase to $7,500,000. Increased initial administrative costs related to qualification and certification would be expected to increase proportionately to $2,525,000, for a total investment cost of approximately $150,000,000.

Paragraph 6.4 discusses the individual values assigned to cost model variables for the diagnostic regime.

Table 6-12. OPERATING COSTS FOR 1972 (THOUSANDS OF DOLLARS)
STATEWIDE NETWORK OF STATE OWNED AND OPERATED
INSPECTION FACILITIES

DIAGNOSTIC TEST

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Salaries of Stationary Facility Inspection Personnel	9,037	4,492	1,328	1,001	1,271	635	308	357	188	30	30
Salaries of Mobile Facility Inspection Personnel	0	0	0	556	116	185	185	116	232	69	46
Salaries of Station Administrative Personnel	2,405	1,230	430	331	317	187	102	116	67	12	12
Equipment Maintenance	99	44	15	15	15	8	5	5	4	1	1
Equipment Depreciation (S/L 10 Years)	99	44	15	15	15	8	5	5	4	1	1
Inspection Facility Maintenance	838	436	130	100	114	57	28	32	18	3	3
Inspection Facility Depreciation (S/L 10 Years)	838	436	130	100	114	57	28	32	18	3	3
Salaries of Program Administrative Personnel	299	219	116	117	116	50	50	50	50	50	50
All Other Program Administrative Operating Costs	32	22	16	42	16	10	10	10	10	10	10
Total: Per Basin	13,647	6,923	2,180	2,277	2,094	1,197	721	723	591	179	156
Parametric High	16,349	8,294	2,612	2,728	2,509	1,434	864	866	708	214	187
Parametric Low	11,054	5,607	1,766	1,844	1,679	960	584	586	479	145	126

ALL BASINS: Total - 30,688; Parametric High - 36,765; Parametric Low - 24,830

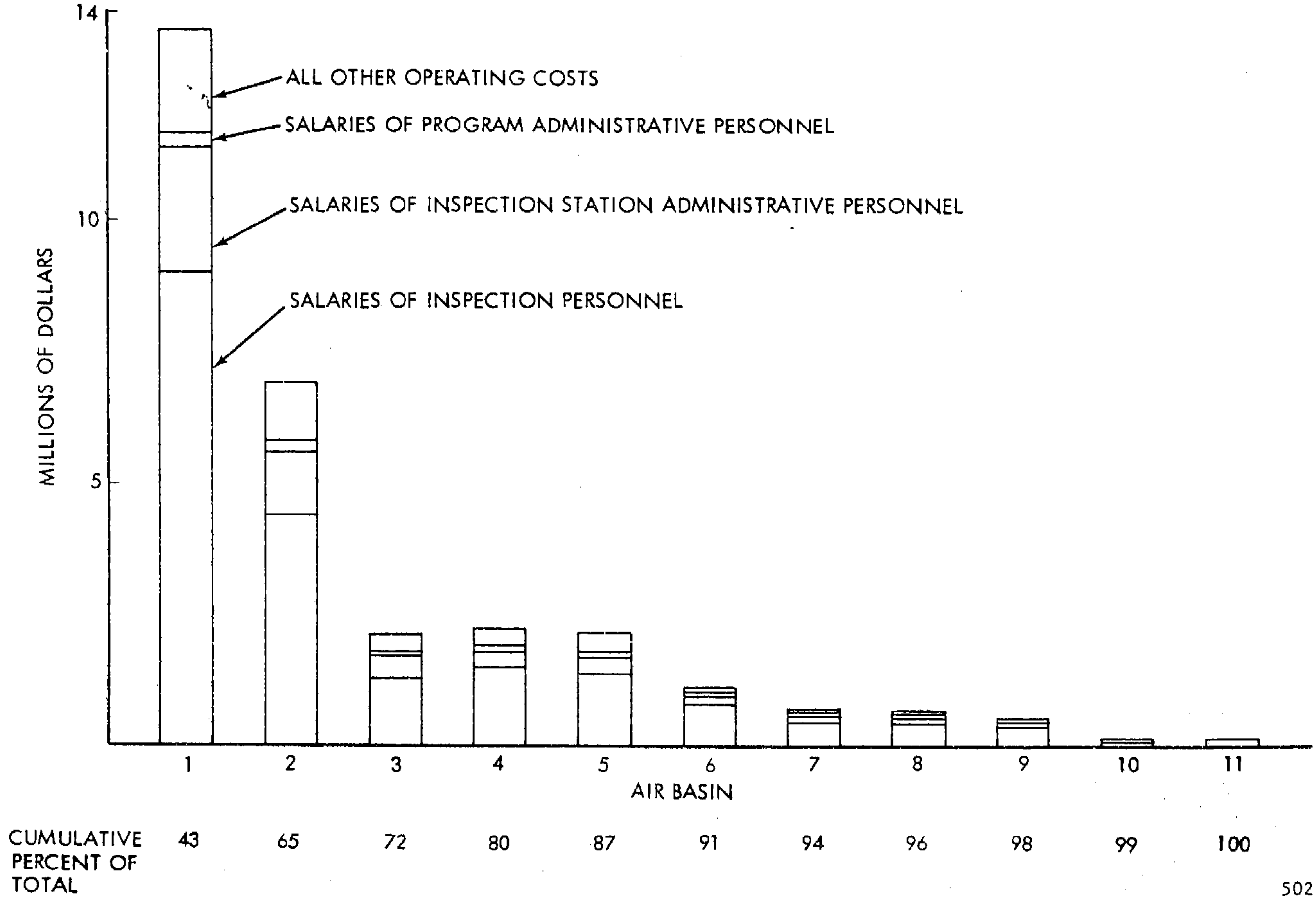

Figure 6-8. DIAGNOSTIC TEST OPERATING COST FOR 1972

Table 6-13. OPERATING COSTS FOR 1972 FOR A PRIVATELY OWNED AND OPERATED, STATE REGULATED SYSTEM OF DIAGNOSTIC EMISSION TEST FACILITIES

Air Basin	1972 Operating Cost
1	$17,332,000
2	8,792,000
3	2,769,000
4	2,892,000
5	2,659,000
6	1,520,000
7	916,000
8	918,000
9	751,000
10	227,000
11	198,000
Total	$38,974,000

6.3.5 Comparative Cost Analysis

The investment and operating costs described in the previous paragraphs are now compared according to the four inspection regimes. The costs have been estimated subject to specified assumptions. However, the cost elements have been presented in such detail that the reader should be able to construct cost estimates based on different assumptions from the data contained in this section.

For example, the cost of a test procedure employing different equipment could be determined by adding the new equipment cost to the other existing investment costs and the operating costs. A modified idle inspection program using the instruments assigned to the Certificate of Compliance would have an equipment acquisition cost of $18,000,000 rather than $50,000,000. If only exhaust emission measurement equipment is required, the additional equipment cost would be only $8,000,000. However, the inaccuracy of the measurement and manhours employed in data handling would increase significantly over those of the recommended configurations represented in these cost estimates.

6.3.5.1 Investment Cost - The following comparative discussion of investment costs of the four test regimes is supplemented by Figure 6-9 and Table 6-14. All costs discussed are based on the State-owned, State-operated configuration of each regime. Readily apparent from either Figure 6-9 or from Table 6-14 is the relative ranking of investment costs of each of the four test regimes. Least costly is idle test at $12,084,000 followed by key mode, Certificate of Compliance, and diagnostic tests at $19,830, 000, $30,263,000, and $88,776,000 respectively. Of the two largest portions of this total investment cost, site acquisition and facility construction, each of the four regimes requires, for site acquisition alone, from a 32 percent low for diagnostic to a 38 percent high for idle, with Certificate of Compliance at 35 percent and key mode at 37 percent. Facility construction takes another large portion of initial investment cost, from a low of 25 percent for idle, to a high of 40 percent for diagnostic, with Certificate of Compliance and key mode at 35 percent and 37 percent, respectively. For these two areas, site acquisition and facility construction, which in all cases comprise at least 59 percent of total investment cost of each test regime, one would expect that the higher throughput regimes, namely idle and key mode, might require a smaller proportion of the total investment cost than would the lower throughput regimes, diagnostic and Certificate of Compliance, primarily because fewer lanes are required for the former cases. This assumption is substantiated in part by the total program investment cost results. The marked exception is the diagnostic regime which requires significantly larger land area and facilities for each operational lane.

Another significant investment cost item, inspection equipment acquisition, consisting of both stationary site inspection acquisition costs and mobile site inspection equipment acquisition costs, comprises a percentage of total investment cost of from 26 percent each for Certificate of Compliance and diagnostic to 29 percent for key mode and 33 percent for idle.

The proportionately equal weighting of instrumentation costs observed between Certificate of Compliance and diagnostic tests reflects the significantly higher instrumentation requirements of the diagnostic regime. Upon failure of each vehicle in this regime, a complete diagnostic instrumentation complement would be required to be available for each diagnostician during malfunction diagnosis.

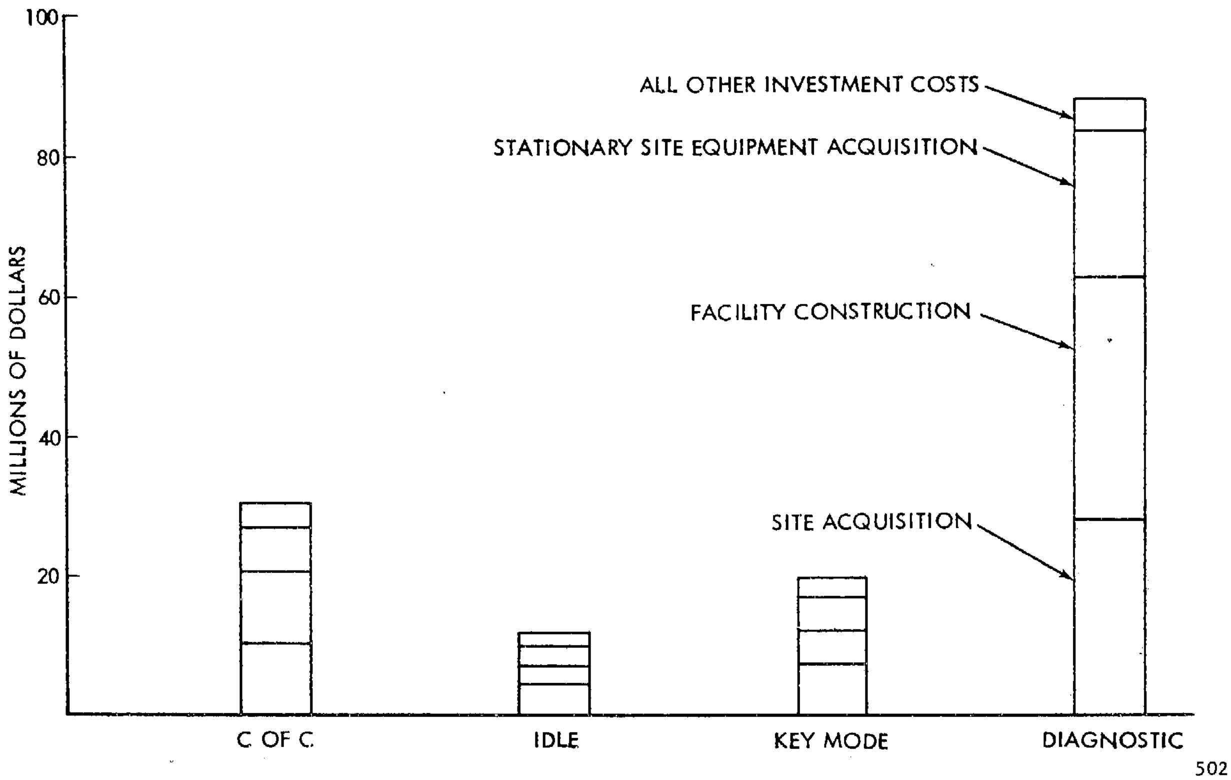

Figure 6-9. COMPARISON OF INVESTMENT COSTS FOR FOUR TEST REGIMES

Table 6-14. INVESTMENT COSTS BY TEST TYPE
(THOUSANDS OF DOLLARS)

Cost Element	C of C	Idle	Key Mode	Diagnostic
Site Acquisition	10,609 (35)*	4,566 (38)	7,315 (37)	28,097 (32)
Facility Construction	10,256 (34)	2,551 (21)	5,130 (26)	35,208 (40)
Stationary Site Inspec Equip	6,365 (21)	3,040 (25)	5,096 (26)	21,060 (24)
Mobile Inspection Equipment	1,490 (5)	1,000 (8)	594 (3)	1,690 (2)
Equipment Installation	-	58	590 (3)	501
Training Costs	703 (2)	97 (1)	173 (1)	1,176 (1)
Facility Plans and Bids	15	15	20	25
Qualification and Certification				
Salaries of Field Personnel	199 (1)	178 (2)	323 (2)	396
Program Administrative Costs	626 (2)	576 (5)	589 (2)	623 (1)
Total Investment Cost	30,263	12,084	19,830	88,776

*Percentage of Total

The equipment installation category applies only to the idle, key mode, and diagnostic regimes, as only they involve nontrivial installation procedures. Of the three regimes, key mode equipment installation represents the greatest portion of investment cost, at 3 percent. Idle and diagnostic equipment installation costs represent less than one percent of the total investment cost of their respective regimes.

Training costs are nominal at one percent of investment cost each for idle, key mode, and diagnostic tests, and two percent for Certificate of Compliance.

The qualification and certification cost category consists of the salaries of field personnel, who would inspect and certify inspection stations, and program administrative costs during the preoperational period of qualification and certification that, in turn, consist of salaries of program administrative personnel and all other program administrative costs incurred during this period. These costs are nominal for all regimes varying from a low of one percent for diagnostic to a high of five percent for idle. These varying percentages, but essentially equivalent absolute magnitudes, are merely indicative of the essentially invariant cost of administering a comprehensive program of mandatory periodic vehicle inspection.

6.3.5.2 Operating Costs - Graphic and tabular summary results of the comparative operating costs of the four test regimes for 1972 are presented in Figure 6-10 and Table 6-15. The following discussion references these two presentations.

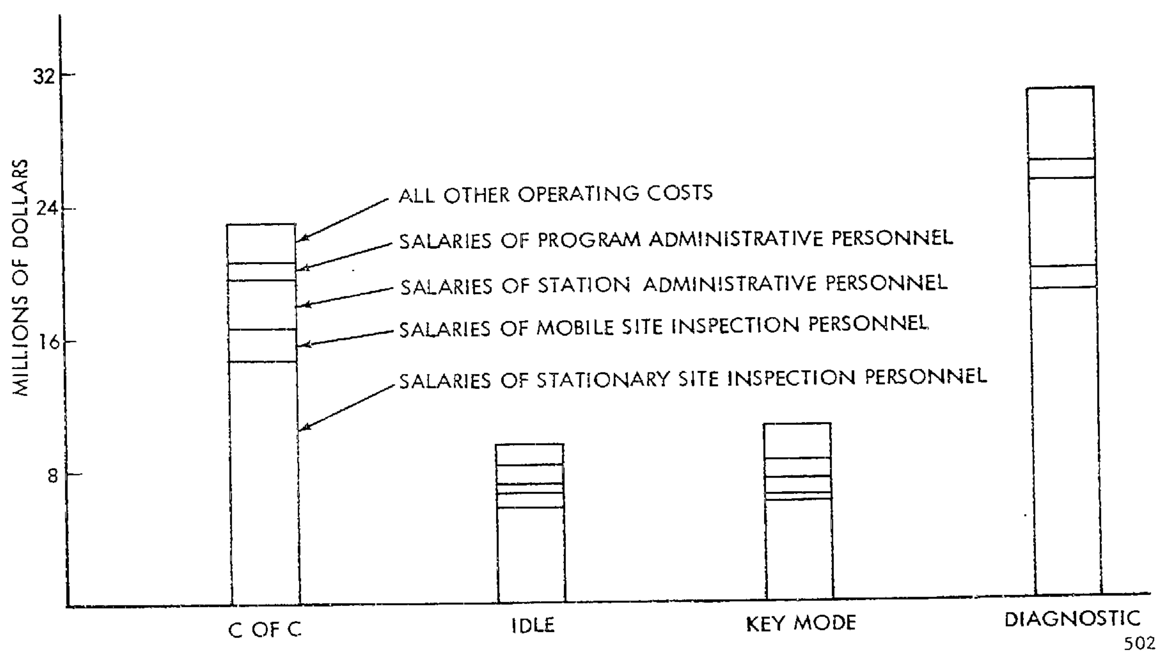

Figure 6-10. COMPARISON OF 1972 OPERATING COSTS FOR FOUR TEST REGIMES

Table 6-15. OPERATING COSTS BY TEST TYPE

Cost Element	C of C	Idle	Key Mode	Diagnostic
Salaries of Stationary Facility Personnel	14,737 (64)*	5,893 (62)	6,131 (59)	18,677 (61)
Salaries of Mobile Facility Personnel	1,749 (8)	742 (8)	517 (5)	1,505 (5)
Salaries of Station Administrative Personnel	2,782 (12)	631 (7)	981 (9)	5,209 (17)
Equipment Maintenance	768 (3)	406 (4)	515 (5)	212 (0.5)
Equipment Depreciation	768 (3)	406 (4)	515 (5)	212 (0.5)
Stationary Inspection Facility Maintenance	511 (2)	128 (1)	258 (2)	1,759 (6)
Inspection Facility Depreciation	511 (2)	128 (1)	258 (2)	1,759 (6)
Salaries of Program Administrative Personnel	1,099 (5)	1,055 (11)	1,103 (11)	1,167 (4)
All Other Administrative Operating Costs	186 (1)	187 (2)	198 (2)	188 (1)
Total	23,110	9,576	10,476	30,688

*Percentage of Total

By far the largest percentage of operating costs of any of these regimes is for inspection facility personnel. Ranging from a high of 72 percent for Certificate of Compliance to a low of 64 percent for key mode, with idle and diagnostic between at 70 percent and 66 percent, respectively, inspection facility inspection personnel salaries clearly dominate the operating cost category. Inspection station administrative personnel salaries vary from 12 percent of the total 1972 operating cost in the case of Certificate of Compliance, to a low of 7 percent for idle. This variation is indicative of the significant difference in vehicle throughput per lane that exists between Certificate of Compliance and idle tests, the former requiring a much larger number of multilane facilities, and consequently a significantly larger number of station administrative personnel. Equipment maintenance and equipment depreciation (10 years, straight-line method) each represent a nominal portion of the total projected 1972 operating cost for each regime, varying from one-half of one percent for diagnostic, to a high of 3 percent for key mode.

Program administrative personnel salaries reflect again in operating costs, as they did in the qualification and certification category of investment costs, the comparable cost required to administer any of these four test regimes. Although their individual percentage representations within a given regime vary from four to eleven percent of operating cost for diagnostic and idle tests, respectively, their absolute magnitudes vary from $1,055,000 for idle to $1,167,000 for diagnostic.

Note the similarity within each regime, in that expected operating costs are consistently significantly lower for the state-owned and state-operated configuration than for a state-licensed configuration. This reflects the inefficiencies suffered by all regimes in terms of total throughput per lane when each regime is relegated to existing facilities, as well as the profit earned by those facilities in performing the required inspections.

We have assumed for purposes of analysis that all equipments have a life of 10 years (10-year straight-line depreciation was used). Consider now the operating costs of each of the four regimes based on 10-year lifetimes assumed for diagnostic consoles, dynamometers, and other heavy equipment, and 5-year lifetimes for gas analyzers and automated data processing equipment. It is assumed in plotting Figure 6-11 that the present worth of all future equipment is equal to that available today. In all cases, a 5 percent annual escalation factor is assumed. See Table 6-16 for a breakdown by year of operating costs of the four test regimes.

Figure 6-11. COMPARATIVE OPERATING COSTS FOR FOUR TEST REGIMES

If an approximation of inspection fees is based on operating cost, merely by dividing the 1972 operating cost by the total number of vehicles to be tested, one would expect comparative fees for the four regimes as presented in Table 6-17, assuming the usual full, statewide implementation in all cases.

Table 6-16. OPERATING COSTS FOR FOUR TEST REGIMES (THOUSANDS OF DOLLARS)

Model Year	C of C	Idle	Key Mode	Diagnostic
1972	23,477	9,978	10,919	33,122
1973	24,651	10,477	11,465	34,778
1974	25,883	11,001	12,038	36,517
1975	27,178	11,551	12,640	38,343
1976	28,536	12,128	13,272	40,260
1977	34,353	17,858	19,950	58,030
1978	31,404	13,347	14,607	44,307
1979	32,974	14,014	15,337	46,522
1980	34,623	14,715	16,104	48,848
1981	36,354	15,406	16,909	51,291
1982	49,131	22,045	26,328	99,905
1983	38,201	16,262	17,948	56,436
1984	40,111	17,075	18,845	59,258
1985	42,117	17,929	19,788	62,221
1986	44,222	18,825	20,777	65,332
1987	53,568	26,830	27,322	80,572
1988	48,669	19,395	22,907	72,018
1989	51,102	20,365	24,052	75,619
1990	53,658	21,383	25,255	79,400

Table 6-17. APPROXIMATE INSPECTION FEES BY TEST AND CONFIGURATION

Configuration	C of C	Idle	Key Mode	Diagnostic
State Owned and Operated	$2.31	$ .96	$1.05	$ 3.07
Privately Owned and Operated, State Regulated	2.94	1.22	1.33	3.90
State Licensed	9.00	6.00	6.00	12.00

6.3.6 Constant Volume Sampling

Constant volume sampling procedures for end of assembly line testing will probably be applied to vehicle surveillance inspections in the future. The anticipated test will be a short (2-minute) dynamometer cycle followed by the sample analysis. Several specific procedures are under investigation by the Air Pollution Control Office of EPA. An approximate cost estimate has been generated from the available information.

Table 6-18. CONSTANT VOLUME SAMPLING SYSTEM INVESTMENT COSTS NETWORK OF NEW FACILITIES (THOUSANDS OF DOLLARS)

Cost Element	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Site Acquisition	3,915	1,897	328	361	420	119	104	134	37	0	0
Facility Construction	2,497	1,292	343	277	314	176	77	100	54	0	0
Stationary Site Inspection Equipment	6,596	3,254	850	646	884	476	204	272	136	0	0
Mobile Site Inspection Equipment	0	0	296	296	0	148	148	74	148	74	37
Equipment Installation	194	192	50	38	52	28	12	16	8	0	0
Training Costs	80	39	13	11	10	7	4	4	3	1	1
Facility Plans and Bids	20	-	-	-	-	-	-	-	-	-	-
Qualification and Certification											
Salaries of Field Personnel Including Travel Allowance and Fringe	42	41	35	38	37	40	30	30	30	0	0
Program Administration Costs	135	100	59	92	57	31	31	31	31	11	11
Total: Per Basin	13,481	6,729	1,948	1,741	1,749	1,012	604	653	443	137	98
Parametric High	16,115	8,041	2,664	2,409	2,081	1,371	885	858	693	240	152
Parametric Low	10,899	5,444	1,699	1,538	1,423	885	553	564	423	147	102

ALL BASINS: Total - 28,595; Parametric High - 35,511; Parametric Low - 21,850

The approximate throughput of vehicles per station is expected to be similar to key mode throughput since the dynamometer cycles are of similar length. The station configurations would therefore be similar as would the total number of stations required. The equipment requirements would change, however, to satisfy the CVS procedure. The dynamometer would require variable inertia loading and power absorption. These features can be added to the key mode dynamometer after it has been installed. The exhaust emission instruments include the constant volume sampler and the appropriate gas analyzers (FID for hydrocarbons, chemiluminescence for NO, and NDIR for CO). The expected incremental cost of the equipment is estimated at $33,000 per inspection lane. This estimate is used to generate Table 6-18, which shows the CVS investment costs by air basin, and Table 6-25, which shows the estimate cost for each station type.

6.4 COST VALUE ASSIGNMENTS

This paragraph describes the rationale for assigning specific values to the individual elements of the cost model. The values assigned to unit costs occurring in all regimes, i.e., unit land costs and equipment costs, are discussed in paragraph 6.4.1. The description of costs analyses for each of the test regimes in paragraph 6.4.2 includes results of exercising the cost model. A listing of symbols and parametric values applicable to the life-cycle cost model is given in Table 6-19. Following this table are Tables 6-20 through 6-25, which provide a listing of cost model variables which vary by air basin and a listing of the dollar amounts for each station configuration of the four test regimes.

All assigned cost values were based on current prevailing rates and represent best estimates available at time of report preparation. Alternate means of financing, such as lease or purchase, all or part of the program costs will not be discussed in this section. In each case discussed below, variable names assigned by the cost model are indicated in parentheses.

6.4.1 Cost Factors Independent of Test Regime

In the consideration of cost factors independent of test regimes, the analysis showed that some cost model elements have the same unit value in all test regimes. These values which do not vary are discussed in the following paragraphs.

6.4.1.1 Investment Costs - Site acquisition (SA) costs depend on facility size (A) and unit land cost (ULC). Unit costs for land purchase (ULC) shown in Table 6-20 were determined for each air basin from commercial realtors. Undeveloped land costs in areas as large as air basins vary significantly, i.e., ±50 percent in the South Coast Air Basin. In general, the fixed facilities would be located in areas already well developed; therefore, the basin-wide average land cost (ULC) has been based on urban land costs within each basin.

Facility construction (FC) costs depend on facility size and unit construction cost (UCC). The unit construction cost (UCC) shown in Table 6-20 depends on the type of test regime, the location, the prevailing wage rates in the area, and the construction material. Cost estimates were prepared by industrial engineering personnel for costs in the South Coast area based on wood frame and stucco materials. The estimates for each regime were based upon double-lane configurations. Stations of different sizes were priced by multiplying the floor area by the unit cost. The costs indicated include land clearance, structure, parking and access areas, and interior building services such as power, a fire extinguisher water-sprinkler system, compressed air, exhaust recovery, space heaters, etc. A detailed description of the configuration of the stations is given in Section 4.

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES

Symbol	Definition	Units	Base Value	Value Range	Remarks
A_o	Program administrative start-up costs	Dollars	Calculated		
A_{ij}	Area, inspection site i, geographic division j	Sq ft	Variable	±20%	See Table 4-3
A_{AOj}	Area, administrative office, in area j	Sq ft	Variable	±20%	See Table 6-20
A_{ES}	Total cost, equipment and supplies, program management	$/year	Calculated		
A_{ESj}	Mean cost, supplies, administrative office, area j	$/year	Variable		See Table 6-20
A_{OS}	Program management office space cost	$/year	Calculated		
A_{Pm}	Administrative personnel costs, program management	$/year	Calculated		
AF_{ij}	Area, facility i, geographic area j	Sq ft	Variable	±20%	See Table 4-3
$APQC_k$	Program administrative personnel, type k, for qualification and certification	Quantity	Variable		See Table 6-20
$APQCW_k$	Wage rate including fringe benefits, administrative personnel for certification, type k	$/day		±20%	
	Facility compliance inspector		$49.30		
	Instrumentation technician		$58.00		
AT	Number of types of program administrative personnel	Quantity	6		
C_{HI}	Classroom hours, inspection trainee	Hours		±20%	
	Certificate of Compliance		68		
	Idle test		59		
	Key mode test		74		
	Diagnostic test		86		

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
C_{HR}	Classroom hours, repair trainee	Hours	Variable	±20%	
	Certificate of Compliance		40		
	Idle test		40		
	Key mode test		40		
	Diagnostic test		40		
C_I	Concurrent number of courses, one inspection, instructor	Quantity	1		
C_{INV}	Total initial acquisition and investment cost	Dollars	Calculated		
C_{OP}	Total operation and maintenance costs	$/year	Calculated		
C_R	Concurrent number of courses, one repair instructor	Quantity	1		
C_{RD}	Total research and development costs	Dollars	Calculated		
CTI	Training cost, inspection facility personnel salaries	$/day	Calculated		
CTR	Training cost, repair personnel salaries	$/day	Calculated		
EA	Inspection facility equipment acquisition	Dollars	Calculated		
EASI EAMI	Total cost of stationary or mobile inspection equipment acquisition	Dollars	Calculated		
EEQC	Certification test equipment set	Dollars/set	Variable	±20%	
	Certificate of Compliance		$7,000		
	Idle test		$15,000		
	Key mode test		$15,000		
	Diagnostic test		$20,000		
EI	Total equipment installation cost	Dollars	Calculated		

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
EIC	Equipment installation cost	Dollars/lane	Variable		
	Certificate of Compliance		$50		
	Idle test		$200		
	Key mode test		$600		
	Diagnostic test		$700		
FC	Facility construction cost	Dollars	Calculated		
FM	Total annual facility maintenance cost	Dollars	Calculated		
F_{MP}	Percentage of facility investment cost allotted for facility maintenance		10%		
H_I	Inspection course mean duration	Days	Variable	±20%	
	Certificate of Compliance		8		
	Idle test		5		
	Key mode test		9		
	Diagnostic test		11		
HM_{ijk}	Hours worked, type k inspection at mobile facility	Hrs/yr	Variable		
	Certificate of Compliance		2000		
	Idle test		2000		
	Key mode test		2000		
	Diagnostic test		2000		
H_R	Course mean duration, repair personnel	Days	Variable		
	Certificate of Compliance		0		
	Idle test		0		
	Key mode test		0		
	Diagnostic test		0		

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
HS_{ijk}	Hours worked, type k inspector at stationary facility	Hrs/yr	Variable		
	Certificate of Compliance		2000		
	Idle test		2000		
	Key mode test		2000		
	Diagnostic test		2000		
HI_{jk}	Wage rate including 25% fringe benefits	\$/hour	Variable	±20%	
	Inspection/test technician III (Diagnostician)		\$8.50		
	Inspection/test technician II		\$6.30		
	Inspection/test technician I		\$4.70		
HR_j	Wage rate including fringe benefits, repair personnel	\$/hour	Variable		
	Class A mechanic		0		
IECM	Initial equipment cost, mobile site	Dollars/Sta	Variable	±20%	
	Certificate of Compliance test				See Table 6-21
	Idle mode test				See Table 6-22
	Key mode test				See Table 6-23
	Diagnostic test				See Table 6-24
IECS	Initial equipment cost, stationary site	Dollars/Sta	Variable	±20%	
	Certificate of Compliance test				See Table 6-21
	Idle test				See Table 6-22
	Key mode test				See Table 6-23
	Diagnostic test				See Table 6-24
IECMAS	Mobile site, initial administrative support equipment cost	Dollars/Sta	Variable	±20%	See IECM

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
IECMSI	Mobile site, initial inspection equipment cost	Dollars/Sta	Variable	±20%	See IECM
IECMS	Mobile site, initial inspection support equipment cost	Dollars/Sta	Variable	±20%	See IECM
IECSAS	Stationary site, initial administrative support equipment cost	Dollars/Sta	Variable	±20%	See IECS
IECSI	Stationary facility initial equipment cost	Dollars/Sta	Variable	±20%	See IECS
IECSS	Stationary facility, initial support equipment	Dollars/Sta	Variable	±20%	See IECS
II	Course fee paid to inspection instructor	Dollars	Variable	±20%	
	Certificate of Compliance		900		15 days
	Idle test		660		11 days
	Key mode test		1080		18 days
	Diagnostic test		1200		21 days
IIC	Inspection instruction cost, inspection and material	Dollars	Calculated		
IP_{ij}	Inspection personnel types	Quantity	Calculated		
IP_{ijk}	Inspection personnel of type k	Quantity	Variable		See Table 4-3
IPT_{ik}	Individual receiving type k training, station i	Quantity	Variable		Same as IP
IR	Course fee plus benefits, repair instructor	Dollars	Variable	±20%	
	Certificate of Compliance		300		5 days
	Idle test		300		5 days
	Key mode test		300		5 days
	Diagnostic test		300		5 days
$ISAP_{ijk}$	Inspection station administrative personnel	Quantity	Variable		See Table 4-4

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
IT	Types of training	Quantity	Variable		
	Certificate of Compliance		1		
	Idle test		1		
	Key mode test		1		
	Diagnostic test		1		
K_e	Escalation factor applied from base year	Quantity	5%		
LCC	Total life cycle program cost	Dollars	Calculated		
M_{AS}	Station administrative support maintenance	$/year	Calculated		
MASP	Percentage of investment cost allotted to administrative support maintenance costs		10%		
M_{EI}	Inspection-oriented equipment maintenance	$/year	Calculated		
M_{EIP}	Percent of investment cost allotted for M_{EI}		10%		
M_{ES}	Inspection-support supplies and equipment maintenance	$/year	Calculated		
M_{ESP}	Percent of investment cost allocated for M_{ES}		10%		
M_{FU}	Facility utilities and maintenance	$/year	Calculated		
M_{FUP}	Percent of investment cost allocated to facilities, taxes		5%		
INS	Certification team inspectors	Quantity	Variable		
	Certificate of Compliance		1		
	Idle test		2		
	Key mode test		2		
	Diagnostic test		2		
n	Index of years in life cycle		Variable		

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
NAP_{jk}	Program administrative personnel, level k, area j	Quantity	Variable		See Table 6-20
NCT	Inspection station certification teams	Quantity	Calculated		
NCT_j	Inspection teams required, area j	Quantity	Calculated		
NI	Inspection course instructors	Quantity	Calculated		
NR	Repair course instructors	Quantity	Calculated		
N_g	Geographic division within state	Quantity	11		
N_j	No. of program administrative levels, area j	Quantity	Variable		See Table 6-20
NS_j	Stations in geographic division j	Quantity	Variable		
OS_j	Office area space cost, area j	$/sq ft/yr	Variable		See Table 6-20
OM_j	Office machines and supplies, area j	Dollars	Variable		See Table 6-20
PB	Facility plans and bids	Dollars	Variable		
	Certificate of Compliance		15,000		
	Idle test		15,000		
	Key mode test		20,000		
	Diagnostic test		25,000		
PRM	Wages, including 35% fringe benefits, type k inspection at mobile facility	$/hour	Variable	±20%	
	Inspection/test technician III		9.35		
	Inspection/test technician II		6.90		
	Inspection/test technician I		5.16		
	Automotive equipment operator		3.81		
PRMAP	Wages, including fringe benefits, mobile facility administrator	$/hour	Variable	±20%	
	Clerk		4.20		

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
PRS_{jk}	Wages, including fringe benefits, type k inspector at stationary inspection facility		Variable	±20%	
	Inspection/test technician III		8.50		
	Inspection/test technician II		6.30		
	Inspection/test technician I		4.70		
$PRSAP_{jk}$	Wages, including fringe benefits, type k administrative stationary facility	\$/hour	Variable	±20%	
	Manager		7.05		
	Assistant manager		6.30		
	Clerk		3.82		
PT	Personnel training cost	\$/year	Calculated		
QC	Station qualification and certification	Dollars	Calculated		
QCW_j	Wages, including fringe benefits, certification field personnel	\$/day	Variable	±20%	
	Facility compliance inspector		49.00		
	Instrumentation technician		58.00		
RIC	Repair instructors and material costs	Dollars	Calculated		
RPT_{ik}	Type k individual at station i receiving repair-oriented instruction	Quantity	Variable		
	Certificate of Compliance		0		
	Idle test		0		
	Key mode test		0		
	Diagnostic test		0		
S_I	Inspection course trainees, mean number	Quantity	Variable		
	Certificate of Compliance		15		
	Idle test		15		

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
	Key mode test		15		
	Diagnostic test		15		
S_R	Repair course trainees, mean number	Quantity	Variable		
	Certificate of Compliance		20		
	Idle test		20		
	Key mode test		20		
	Diagnostic test		20		
Sa_{jk}	Program management administrative personnel, level k, area j, salaries	\$/year	Variable	±20%	
	Program manager		17,750		
	Regional air basin manager		16,000		
	Secretary		10,300		
	Clerk		7,620		
	Facility compliance inspector		12,300		
	Instrumentation technician		14,500		
S_{AP}	Salaries, wages, benefits, station administrative personnel	\$/year	Calculated		
S_{IP}	Salaries, wages, benefits, station inspection personnel	\$/year	Calculated		
SA	Inspection site acquisition	Dollars	Calculated		
ST	Stationary or mobile inspection facility types	Quantity	Variable		
	Certificate of Compliance				
	Stationary		7		1-7 lanes
	Mobile		1		

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
	Idle test				
	Stationary		7		1-7 lanes
	Mobile		1		
	Key mode test				
	Stationary		7		1-7 lanes
	Mobile		1		
	Diagnostic test				
	Stationary		7		1-7 lanes
	Mobile		1		
T_{IK}	Mean time required, certify one type k station	Hours/lane	Variable		
	Certificate of Compliance		4		
	Idle test		4		
	Key mode test		4		
	Diagnostic test		6		
T_I	Inspection training period	Days	Variable		
	Certificate of Compliance		15		
	Idle test		11		
	Key mode test		18		
	Diagnostic test		21		
T_{QC}	Station certification allowed time	Days	Variable		
	Certificate of Compliance		90		
	Idle test		90		
	Key mode test		90		
	Diagnostic test		90		

Table 6-19. LIFE CYCLE COST MODEL SYMBOLS AND PARAMETRIC VALUES (Continued)

Symbol	Definition	Units	Base Value	Value Range	Remarks
T_R	Repair training period	Days	Variable		
	Certificate of Compliance		5		
	Idle test		5		
	Key mode test		5		
	Diagnostic test		5		
TC_j	Transportation allowance, certified field personnel	\$/day	\$25	±20%	
T_I	Initial training and indoctrination cost	Dollars	Calculated		
TT	Mean travel time between stations, certified field personnel	Days	0.04		
UCC_j	Facility construction cost, area j	\$/sq ft			See Table 6-20
ULC_j	Land cost, geographic division j	\$/sq ft			See Table 6-20
W	Working days in one calendar year	Days	250		
Y	Life cycle duration	Years	20		
δ_{ije}	Summation variable	1 if facility (ij) is not a currently existing facility which may be altered for use in periodic inspection 0 if facility (ij) may be altered for use immediately with only equipment additions or changes.			
ϵ_{ijs}	Summation variable	1 if facility i in georgraphic division j is stationary 0 if mobile.			
ϵ_{ijm}	Summation variable	1 if facility i in area j is mobile 0 otherwise.			

Table 6-20. LIFE CYCLE COST MODEL BASE VALUES BY AIR BASIN

	Air Basin										
	1	2	3	4	5	6	7	8	9	10	11
Symbol	SC	SFBA	SJV	ScV	SD	SED	NCC	SCC	NC	NP	GBV
A_{AO}	600	525	300	750	225	225	225	225	225	225	225
A_{ES}	30,000	20,000	15,000	40,000	15,000	10,000	10,000	10,000	10,000	10,000	10,000
$APQC_1$	0	0	0	1	0	0	0	0	0	0	0
$APQC_2$	1	1	1	1	1	1	1	1	1	1	1
$APQC_3$	1	1	0	1	0	0	0	0	0	0	0
$APQC_4$	4	3	2	6	2	1	1	1	1	1	1
$APQC_5$	15	10	5	5	1	1	1	1	1	1	1
$APQC_6$	2	2	1	1	1	1	1	1	1	1	1
NAP_1	0	0	0	1	0	0	0	0	0	0	0
NAP_2	1	1	1	1	1	1	1	1	1	1	1
NAP_3	1	1	0	1	0	0	0	0	0	0	0
NAP_4	4	3	2	6	2	1	1	1	1	1	1
NAP_5	15	10	5	5	1	1	1	1	1	1	1
NAP_6	2	2	1	1	1	1	1	1	1	1	1
O_S	$36.00	$42.00	$30.00	$30.00	$24.00	$24.00	$24.00	$30.00	$24.00	$24.00	$24.00
O_M	$8,000	$7,000	$4,000	$10,000	$4,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
UCC_k	$7.00	$7.50	$7.00	$7.00	$6.75	$6.75	$6.75	$6.75	$6.75	$6.75	$6.75
ULC_k	$2.50	$2.50	$1.50	$2.00	$2.00	$1.00	$2.00	$2.00	$1.00	$1.50	$1.00

See Table 6-19 for an explanation of headings and symbols.

Since costs could vary significantly, depending on the station location, the California Business and Transportation Agency's document on Statewide Prevailing Wage Rates was used to develop a coefficient which could be applied to the Southen California cost estimate.

The costs were determined for the one construction method, wood frame, and stucco. These costs were estimated by industrial engineering personnel to be higher than metal frame and siding structures and less than precast concrete or cinder block construction. Since it was a universally applicable construction method, and since it provides better insulation than either of the other techniques, it was used as a reference base. These costs were then varied ±20 percent to provide upper and lower limits for construction costs.

Equipment acquisition (EA) has been separated for mobile and stationary facilities. They were further divided into inspection equipment (IECMI, IECSI), support equipment (IECMS, IECSS), and administrative support equipment (IECMAS, IECSAS). In each case, the first variable name refers to mobile facilities, the second to stationary ones. These costs were developed by determining the number of equipment of each type required and their individual unit costs. For the inspection equipment, unit costs were determined for lots of 100 units. The instruments and equipment selected for cost analysis were identified in the analysis in Section 3. Costs were estimated based on information supplied by the respective manufacturers for similar production instruments. The average cost of the top ranked instruments was used as a base value and then varied ±20 percent to account for any variation in the final equipment selection or changes in unit costs. The numbers of each equipment type were determined in the equipment requirements section of Section 4.

Inspection-support equipment costs (IECMS, IECSS) were estimated from possible equipments needed for adjustment, calibration, and testing of the inspection equipment. It was assumed that the amount of IECSS in each system category was proportional to that system's initial inspection equipment costs. IECMS included such items as the van to transport test personnel and equipment, dynamometer, and power plant, plus the regular inspection-support equipment.

Administrative support equipment costs (IECMAS, IECSAS) were assigned to the office equipment and record storage equipment required in the various inspection stations. Not included was the record storage and printout equipment which was integral with the inspection instrument package. Should a typical station require additional record keeping equipment, such as in the Certificate of Compliance station, it can be added for relatively nominal cost. The administrative support costs for the stationary stations included office equipment items such as desks and chairs, file cabinets, card files, and chairs for public use. Administrative support equipment costs for mobile sites were defined 0 since the record files and desks would be built into the van, and, therefore, assignable to inspection support equipment costs. Costs were assigned on the basis of prevailing costs for office furniture in Southern California.

Equipment installation costs (EIC) were estimated from the number of manhours required to place, install, and acceptance-test the various equipments. The costs were assigned to the dynamometer ($500), exhaust analysis, and engine diagnostic equipment at $50 per unit, and office equipment at $100 per set. Configurations which used existing buildings included installation cost for the dynamometer pits, inspection pits, and exhaust recovery system or necessary changes to the building utilities or interior. In this case, an additional cost increment of $1000 was assigned to the necessary interior modifications for each dynamometer installation. Major interior modification for stations without dynamometers was not required since the installation would probably be placed in existing garages.

Personnel training (TI) costs depend on several factors, the only one which changes with the test regime being the number of hours (CH_I, H_I) required for classroom and total training requirements. The personnel qualifications and requirements are defined in paragraph 4.7. The instructors' pay rates (TI) are $300 per week which is calculated for each regime in terms of total dollars per course. This fee is competitive with existing automotive maintenance and diagnostic work in public and private schools. It was assumed that classroom space is available in public schools or the inspection facilities for nominal cost. No training was assigned to repair personnel; therefore, a single type of training (IT) was offered for each test regime. The mean class size (S_I) for each test regime was taken as 15 trainees.

Station Qualification and Certification costs included the salary costs of the inspectors operating from the regional offices, the cost of their equipment (EEQC), the time required to inspect the various stations (T_k), and the time allowed for certification of all stations (T_{QC}), which was taken as 90 working days for all regimes. The qualification teams are equipped with the same measurement instruments as the stations so that they can perform simultaneous measurements with the station instruments to verify equivalent calibration and operation. The certification teams can also serve as mobile Certificate of Compliance and Idle inspection stations, except for the lack of independent power.

6.4.1.2 <u>Operating Costs</u> - The largest operating cost is salaries of station inspectors for stationary and mobile sites (SIPS, SIPM), station administrators (SAPS, SAPM), and program management personnel (AP). Pay rates were not varied among air basins since wage rates paid by the State were assumed representative of prevailing wages. Wage rates were varied ±20 percent to provide an expected range of pay levels which might occur because of different job classifications or differences in wage rates between regions. Wage rates of inspection personnel for stationary and mobile site personnel (PRS, PRM) were determined by examination of existing garage and diagnostic center wage rates for mechanics, tuneup man, and diagnosticians. Wage rates among the inspectors must be commensurate with the prevailing wages for personnel with the desired skills. All administrative personnel pay rates (APQCW, NAP, PRSAP) were determined from the California Personnel Department wage rate books which show job classifications and pay rates. Administrative personnel were assigned pay rates prevailing in the Department of Motor Vehicles (clerical and management), the Air Resource Board (instrumentation technician), and the Highway Patrol (facility inspectors). During analysis it was assumed that the State would maintain an orderly program implementation and utilize the same staff for program management (NAP) as during program implementation and station qualification and certification (APQC).

Stationary and mobile personnel would receive different pay rates. Mobile personnel are assigned an additional 10 percent hardship bonus to compensate for time away from the regional office. The mobile team will not have the equivalent of the station administrator. All administrative functions will be carried out either by the inspectors or by the regional office personnel.

Maintenance costs include maintenance for the inspection equipment (M_{EI}), inspection support equipment (M_{ES}), administrative support equipment (M_{AS}), continuing facility upkeep, and periodic maintenance of the facility structure and grounds (M_{FU}). The elements which comprise these costs generally were not available from manufacturer data. Rudimentary operational experience, an estimate of component costs, and accepted industrial engineering practice were used to generate estimated percentage factors which are applied to the appropriate initial investment cost to determine the respective maintenance costs. These factors were tabulated in Table 6-19.

Inspection equipment maintenance (M_{EI}) included technician service time, parts, as well as calibration gases and other expendable supplies related to the sample system, analysis, data processing package, and dynamometers.

Inspection support equipment (M_{ES}) included service time, parts, and expendable supplies related to the inspection support equipments such as exhaust recovery systems or other support equipments related to test performance. Included in this cost is the central laboratory at the air basin regional office which provides repair services, preventive maintenance, and calibration check.

Administrative support equipment maintenance (M_{AS}) provides maintenance services and office supply costs to the station administrative services. These costs include service of office equipment, replacement cost for equipment and necessary office supplies in the inspection station. Included is upkeep on equipment provided for the general public.

Facilities maintenance (FM) includes operating costs of the facilities, including utilities, taxes, profit (if private), cleaning of the plant and grounds, and repainting of the structure or any other repairs.

Mean costs of supplies per regional office (A_{ES}) were estimated from the probable work load and transactions required in the office. The amounts were proportional to the number of vehicles per air basin. Regional office space costs (A_{OS}) were determined by real estate operators for the urban regions of each air basin. Both values are shown in Table 6-20.

6.4.2 Cost Model Variables Dependent on Test Regime

Paragraph 6.4.1 has described the cost model elements which do not vary between test regimes. This paragraph describes those cost elements which do differ between the four test regimes. The major cost categories are based on numbers of units which differ according to the test regime and the station size, and the units costs. The unit costs were previously described in paragraph 6.4.1. The numbers of units were described in Section 4. The average costs for these items are shown in Tables 6-21 through 6-25 for each configuration of the stations in each test regime. The costs for land and facility acquisition are approximate since these unit costs vary between air basins. Other factors, not previously mentioned quantitatively, were found to vary with the test regime. Although these other factors are not significant in determining program costs, they are included in the cost model and in the master cost table, Table 6-19.

6.4.2.1 Certificate of Compliance - The principal program cost factors are the equipment, facility, land, and personnel costs, as shown in Table 6-21. The Certificate of Compliance program does not require any R&D effort. The indicated investment costs for land and facilities are intended for a State owned and operated system. For the alternative configuration of existing privately owned stations, these capital investment costs are eliminated. The equipment cost depends on the required instruments. The State owned and operated stations include diagnostic and inexpensive emission measurement instruments. These costs would decrease depending on the equipment initially possessed by the participating private garages.

Table 6-21. COST MODEL VARIABLES FOR CERTIFICATE OF COMPLIANCE INSPECTION STATIONS[1]

Cost Element	Station Type: Mobile	1	2	3	4	5	6	7
Investment Costs								
Equipment								
Inspection (5 yr depr)	1,600	1,600	3,200	4,800	6,400	8,000	9,600	11,200
Inspection (10 yr depr)	2,000	2,000	4,000	6,000	8,000	10,000	12,000	14,000
Support	4,000	0	0	0	0	0	0	0
Administrative	0	900	1,050	1,200	2,000	2,150	3,000	3,150
Installation	0	50	100	150	200	250	300	350
Site Acquisition								
Land Area	0	7,190	10,000	17,190	20,000	27,190	30,000	37,190
Land Cost ($2/sq ft)[2]	0	14,380	20,000	34,380	40,000	54,380	60,000	74,380
Construction Cost								
Facility Area	0	1,370	2,040	3,410	4,080	5,450	6,120	7,490
Facility Cost ($7/sq ft)[2]	0	10,960	16,320	27,280	32,640	43,600	48,960	59,920
Total	7,600	29,890	44,670	74,810	89,240	118,380	133,860	163,000
Operating Costs								
Personnel (SA)[3]								
Manager I	0	0	0	0	0	0	12,600	12,600
Clerk	0	0	0	0	7,640	7,640	7,640	7,640
Technician III	18,700	17,000	34,000	51,000	68,000	85,000	102,000	119,000
Supplies and Maintenance								
Inspection	360	360	720	1,080	1,440	1,800	2,160	2,520
Support	400	0	0	0	0	0	0	0
Administrative	100	90	105	120	200	215	300	315
Facilities and Grounds	0	550	816	1,362	1,635	2,190	2,450	3,000
Total	19,560	18,000	35,641	53,562	78,915	96,845	127,150	145,075

(1) Costs invariant by test regime are presented in Table 6-19
(2) Average unit costs; actual values vary by Air Basin, Table 6-20
(3) Salaries and fringe benefits - 2000 hrs/yr

Personnel training costs include 68 hours of lecture and demonstration (CH_I) and 48 hours on the job training for a total period of 116 hours (H_I) at full pay (HI). All inspection personnel in the Certificate of Compliance program receive the same training course (IT).

The Station Qualification and Certificate costs include the $7,000 for the qualification equipment (EEQC), consisting of the emission instruments and supplies, and vehicle and the Certification personnel. One facility compliance inspector (INS) is required to spend 4 hours (T_k) with each inspection station inspector to ensure his competence with the equipment and required procedures. The certification inspectors travel from the regional center of each air basin. Therefore, they are allowed travel expenses and $25 when away from their home city.

6.4.2.2 Idle Mode - Table 6-22 shows the major investment and operating costs for the Idle Mode stations. The principal investment costs are the land, facilities, and equipment. For existing garages participating in a State licensed program, the facility and land costs would be deleted. A $10,000 per lane emission test and recording system was identified during the instrument analysis as desirable in the State owned and operated system. This system has the ability to provide automatic dilution calculations and determination of pass/fail vehicle emission certification. A $200,000 development program is anticipated for this system. This same instrument package was included in the cost estimate for the privately owned and operated Idle Mode inspection stations. If the private garages performing inspections were permitted to install the less expensive engine diagnostic emission analyzers (5 percent accuracy) the equipment costs would be lower than shown on these tables. This situation is discussed briefly in paragraph 6.3.5.

The personnel cost for the Idle station is the lowest of those considered because of the simple nature of the test. The training program is also the shortest. The inspection personnel are required to take an 87 hour (H_I) training course including 59 hours (CH_I) of lecture and demonstrations. The trainees are paid full time (HI) during the training period. Even though two levels (IP) of inspectors are used in the Idle stations, the single training course (IT) is taken by all station inspection personnel.

The Station Certification and Qualification costs, which include the equipment complement of the inspectors (EEQC), is now priced at $15,000 dollars including the sampling, data processing system, gas analyzers, and vehicle. The inspection team consists of two persons, the Facility Compliance Inspector who determines the physical ability of the station to process vehicles and certifies the performance and skill level of the lane inspectors, and an Instrumentation Technician who verifies instrument performance and operation. These two persons do not necessarily travel together, since the performance of the personnel may take longer to certify than the performance of the instruments. The average time to certify a lane (T_k) is again specified at 4 hours.

6.4.2.3 Key Mode - Table 6-23 shows the major cost categories for the Key Mode stations. The equipment required by the Key Mode station is valued at $12,000 per lane for the inspection oriented equipment. Equipment costs are not significantly higher than for Idle stations equipped with the semiautomative data system previously described. The $200,000 R&D cost, therefore, is still required for system development. Manual methods of processing data and certification records would probably not be satisfactory for the high throughput State owned and operated stations.

Table 6-22. COST MODEL VARIABLES FOR IDLE INSPECTION STATIONS[1]

Cost Element	Station Type							
	Mobile	1	2	3	4	5	6	7
Investment Costs								
Equipment (EA)								
Inspection (5 yr depr)	11,000	10,000	20,000	30,000	40,000	50,000	60,000	70,000
Inspection (10 Yr depr)	0	0	0	0	0	0	0	0
Inspection Support (10 yr depr)	12,000	1,000	2,000	3,000	4,000	5,000	6,000	7,000
Administrative	0	1,000	1,700	2,000	2,000	2,800	3,000	3,000
Installation	0	200	400	600	800	1,000	1,200	1,400
Site Acquisition (SA)								
Land Area (A)	0	7,190	10,000	17,190	20,000	27,190	30,000	37,190
Land Cost ($2/sq ft)[2]	0	14,380	20,000	34,380	40,000	54,380	60,000	74,380
Construction Cost (FC)								
Facility Area (AF)	0	1,370	2,040	3,410	4,080	5,450	6,120	7,490
Facility Cost ($8/sq ft)[2]	0	10,960	16,320	27,280	32,640	43,600	48,960	59,920
Total	23,000	37,540	60,420	97,260	119,440	156,780	179,160	215,700
Operating Costs								
Personnel[3]								
Manager II	0	0	0	0	0	0	14,100	14,100
Manager I	0	0	0	0	12,600	12,600	0	0
Clerk	0	0	0	7,640	0	7,640	7,640	7,640
Technician II	13,900	12,600	25,200	50,400	50,400	75,600	75,600	100,800
Technician I	10,350	9,400	18,800	18,800	37,600	37,600	56,400	56,400
Supplies and Maintenance								
Inspection Equipment	1,100	1,000	2,000	3,000	4,000	5,000	6,000	7,000
Support	1,200	100	200	300	400	500	600	700
Administrative	0	100	170	200	200	280	300	300
Facilities and Grounds	0	548	816	1,386	1,632	2,180	2,450	2,985
Total	26,550	23,748	47,186	81,726	106,832	141,400	163,090	189,925

(1) Costs invariant by test regime are shown in Table 6-19
(2) Average unit costs; actual value varies by Air Basin, Table 6-20
(3) Salaries and fringe benefits - 2000 hrs/year

Table 6-23. COST MODEL VARIABLES FOR KEY MODE INSPECTION STATIONS(1)

	Station Type							
Cost Element	Mobile	1	2	3	4	5	6	7
Investment Costs								
Equipment (EA)								
Inspection (5 yr depr)	11,000	10,000	20,000	30,000	40,000	50,000	60,000	70,000
Inspection (10 yr depr)	2,000	2,000	4,000	6,000	8,000	10,000	12,000	14,000
Inspection Support	5,000	1,000	2,000	3,000	4,000	5,000	6,000	7,000
Administrative	0	1,000	1,700	2,000	2,000	2,800	3,000	3,200
Installation	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000
Site Acquisition								
Land Area	0	10,900	15,110	26,010	30,220	41,120	45,330	56,230
Land Cost(2)	0	21,800	30,220	52,020	60,440	82,240	90,660	112,460
Construction Cost								
Facility Area	0	2,040	3,060	5,100	6,120	8,160	9,180	11,220
Facility Cost(2)	0	16,320	24,480	40,800	48,960	65,280	73,440	89,760
Total	18,000	53,120	84,400	136,820	167,400	220,320	251,100	303,420
Operating Cost								
Personnel: Salaries and Fringe(3)								
Manager II	0	0	0	0	0	0	14,100	14,100
Manager I	0	0	0	0	12,600	12,600	0	0
Clerk	0	0	0	7,640	0	7,640	7,640	7,640
Technician II	13,900	12,600	25,200	37,800	50,400	63,000	75,600	98,200
Technician I	10,300	9,400	18,800	28,200	37,600	47,000	56,400	65,800
Supplies and Maintenance								
Inspection	1,300	1,200	2,400	3,600	4,800	6,000	7,200	8,400
Support	500	100	200	300	400	500	600	700
Administrative	0	100	170	200	200	280	300	320
Facility and Grounds	0	816	1,224	2,040	2,448	3,264	3,672	4,488
Total	26,000	24,216	47,994	79,780	108,448	140,284	165,512	199,648

(1) Costs invariant by test regime are shown in Table 6-19
(2) Average unit costs; actual values vary by Air Basin, Table 6-20
(3) Salaries and fringe benefits - 2000 hrs/year

The facilities for Key Mode required more space than the Idle or Certificate of Compliance stations. The personnel assignments are similar to the Idle stations; however, the training program is more involved. A total of 142 hours (H_I), including 74 hours of lecture and demonstration (CH_I), are required. The trainees are paid full time (HI) during the entire training program.

The Station Qualification and Certification costs include the $15,000 certification equipment (EEQC) consisting of emission measurement, supplies, and vehicle. The two station certification inspectors described for the Idle stations (INS), and 4 hours (T_k) per lane to inspect and certify the inspection lane is still required.

6.4.2.4 Diagnostic Inspection - The principal costs are shown in Table 6-24. The facility and resulting land requirements are greatest of the four regimes because of the diagnostic stalls required. A set of engine diagnostic equipment is required at the dynamometer and at each diagnostic stall. In addition, each diagnostic stall requires the emission measurement instruments for HC and CO. The mobile stations require only two engine diagnostic systems and one emission measurement instrument for HC and CO, since the mobile Diagnostic stations were only staffed with two Technician III diagnosticians.

Each inspector at the diagnostic stations, regardless of skill level, required the same 174 hour (H_I) course including the 86 hours (CH_I) of lecture and demonstrations.

Station Qualification and Certification costs include the certification equipment (EEQC) valued at $20,000 for the instrument system, engine diagnostic equipment, supplies and vehicle, and the cost of the certification team. Two inspectors (INS) are included in the team, the Facility Compliance Inspector and the Instrumentation Technician. The time required to certify one inspection lane and the associated diagnostic stalls in 6 hours was due to the larger number of inspection personnel assigned and the greater sophistication of the inspection process.

6.4.2.5 Constant Volume Sampling - Table 6-25 shows the additional equipment costs for CVS procedures added to Key Mode stations.

6.5 VEHICLE OWNER'S COST ANALYSIS

The owners of vehicles that fail an emission inspection will be faced with the cost of repairs to bring the emission level to an acceptable value.

Based on the service performed on 318 of the 523 vehicles tested as of 1 May 1971, cost averages were obtained for each of the test regimes. The cost was segregated into categories of parts (not including sales taxes), and labor. In addition to the cost average for all service performed on a set of vehicles, the average was calculated for costs resulting from performance of first service only. Since many cars were dispatched for service more than once, it was useful to determine the cost of additional service beyond the first service, and this cost will be used in Section 8 in the determination of cost effectiveness of service to the vehicle owner.

A summary and comparison of vehicle owner costs by test regimes will be presented in paragraph 6.5.5. Of general interest are the averages for all 318 vehicles services (the serviced fleet). Tables 6-26 and 6-27 present these averages for the set of all vehicles and the controlled and uncontrolled subsets.

Table 6-24. COST MODEL VARIABLES FOR DIAGNOSTIC INSPECTION STATIONS[1]

Cost Element	Station Type							
	Mobile	1	2	3	4	5	6	7
Investment Costs								
Equipment (EA)								
Inspection (5 yr S/L depr)	14,000	14,000	28,000	42,000	56,000	70,000	84,000	112,000
Inspection (10 yr S/L depr)	12,000	18,000	36,000	54,000	72,000	90,000	108,000	126,000
Support	9,000	3,000	6,000	10,000	12,000	15,000	18,000	21,000
Administrative	0	1,550	3,100	4,650	6,200	7,750	9,300	10,850
Installation	0	700	1,400	2,100	2,800	3,500	4,200	4,900
Site Acquisition (SA)								
Land Area	0	25,800	33,000	58,800	66,000	91,800	99,000	124,800
Land Cost ($2/sq ft)[2]	0	51,600	66,000	119,600	132,000	183,600	198,000	249,600
Construction Cost (FC)								
Facility Area	0	10,100	12,600	22,700	25,200	35,300	37,800	47,900
Facility Cost ($7/sq ft)[2]	0	70,700	88,200	158,900	176,400	227,100	264,600	315,300
Total	35,000	159,550	228,700	391,250	457,400	596,950	686,100	839,650
Operating Cost								
Personnel[3]								
Manager II	0	0	0	0	0	14,100	14,100	14,100
Manager I	0	0	12,600	12,600	12,600	0	12,600	12,600
Clerk	0	7,640	7,640	7,640	14,280	14,280	14,280	14,280
Technician III $8.05	17,700	32,200	64,400	96,600	128,800	161,000	193,200	225,400
Technician II $6.30	13,900	12,600	25,200	37,800	50,400	63,000	75,600	88,200
Technician I $4.70	0	9,400	18,800	28,200	37,600	47,000	56,400	65,800
Supplies and Maintenance								
Inspection	2,600	3,200	6,400	9,600	12,800	16,000	19,200	23,800
Support	900	300	600	1,000	1,200	1,500	1,800	2,100
Administrative	0	155	310	465	620	775	930	1,085
Facility and Grounds	0	3,530	4,410	7,930	8,780	11,355	13,200	15,765
Total	35,100	69,025	140,360	201,835	267,080	329,010	401,310	463,130

(1) Costs invariant by test regime are shown in Table 6-19
(2) Average unit costs; actual value varies by Air Basin, Table 6-20
(3) Salaries and fringe benefits - 2000 hours/year

Table 6-25. COST MODEL VARIABLES FOR CONSTANT VOLUME SAMPLING SYSTEM INSPECTION STATIONS[1]

Cost Element	Station Type							
	Mobile	1	2	3	4	5	6	7
Investment Costs								
Equipment (EA)								
Inspection (5 yr depr)	16,000	16,000	32,000	48,000	64,000	80,000	96,000	104,000
Inspection (10 yr depr)	7,000	7,000	14,000	21,000	28,000	35,000	42,000	49,000
Inspection Support	5,000	1,000	2,000	3,000	4,000	5,000	6,000	7,000
Administrative	0	1,000	1,700	2,000	2,000	2,800	3,000	3,200
Installation	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000
Site Acquisition								
Land Area	0	10,900	15,110	26,010	30,220	41,120	45,330	56,230
Land Cost[2]	0	21,800	30,220	52,020	60,440	82,240	90,660	112,460
Construction Cost								
Facility Area	0	2,040	3,060	5,100	6,120	8,160	9,180	11,220
Facility Cost[2]	0	16,320	24,480	40,800	48,960	65,280	73,440	89,760
Total	28,000	64,120	106,400	169,820	211,400	275,320	317,100	372,420
Operating Cost								
Personnel: Salaries and Fringe[3]								
Manager II	0	0	0	0	0	0	14,100	14,100
Manager I	0	0	0	0	12,600	12,600	0	0
Clerk	0	0	0	7,640	0	7,640	7,640	7,640
Technician II	13,900	12,600	25,200	37,800	50,400	63,000	75,600	98,200
Technician I	10,300	9,400	18,800	28,200	37,600	47,000	56,400	65,800
Supplies and Maintenance								
Inspection	2,300	2,300	4,600	6,900	9,200	11,500	13,800	15,300
Support	500	100	200	300	400	500	600	700
Administrative	0	100	170	200	200	280	300	320
Facility and Grounds	0	816	1,224	2,040	2,448	3,264	3,672	4,488
Total	27,000	25,316	50,194	83,080	112,448	145,784	172,112	206,548

(1) Costs invariant by test regime are shown in Table 6-19
(2) Average unit costs; actual values vary by Air Basin, Table 6-20
(3) Salaries and fringe benefits - 2000 hrs/year

Table 6-26. FLEET SERVICE COST AVERAGES (PARTS AND LABOR) IN DOLLARS

Vehicle Group	After All Service		After First Service		Cost of Additional Service	
	Parts	Labor	Parts	Labor	Parts	Labor
Controlled (126)	7.83	11.59	6.06	9.76	1.77	1.82
Uncontrolled (186)	11.01	19.45	8.75	14.59	2.26	4.86
All Vehicles (312)	9.73	16.27	7.66	12.64	2.06	3.63

Table 6-27. FLEET SERVICE COST AVERAGES (TOTALS) IN DOLLARS

Vehicle Group	After All Service	After First Service	Cost of Additional Service
Controlled (126)	19.42	15.82	3.60
Uncontrolled (186)	30.46	23.18	7.28
All Vehicles (312)	26.00	20.21	5.79

6.5.1 Certificate of Compliance Repair Costs

The cost of the Certificate of Compliance service to the car owner represents, for controlled cars, the present rate of cost for this test throughout the state. The cost of the inspection is in most cases indistinguishable from the adjustment performed. The cost for performance of the Certificate of Compliance inspection is higher than normal for uncontrolled cars because of modifications imposed on the inspection by the current study. The modification required that uncontrolled cars be subjected to essentially the same test and adjustments as controlled cars.

By design, there were no pass/fail limits; all cars were sent to Official Motor Vehicle Pollution Control Stations for certification. The costs incurred for this certification did not vary significantly from the controlled set to the uncontrolled set, or from first service to all service as shown in Table 6-28.

Based on the vehicles serviced, the vehicle owner would expect to pay, on the average, \$8.92 for the Certificate of Compliance on controlled vehicles, and \$7.73 for the modified Certificate of Compliance for uncontrolled vehicles, or a composite average of \$8.31.

6.5.2 Idle Test Repair Cost

The ground rules for repairs to cars in the Idle test regime were to simply perform any repairs necessary to bring the CO and HC for the car being tested within prescribed limits. A set of adjustments was first performed in an attempt to lower the emission levels. When these adjustments were found to be insufficient,

Table 6-28. AVERAGE CERTIFICATE OF COMPLIANCE COSTS IN DOLLARS

Service Phase	Controlled (61)	Uncontrolled (64)	All Vehicles (125)
After All Service			
Parts	1.30	1.09	1.19
Labor	7.62	6.64	7.12
Total	8.92	7.73	8.31
After First Service			
Parts	1.07	1.06	1.06
Labor	7.10	6.56	6.82
Total	8.17	7.62	7.88

additional appropriate repairs were authorized. In actuality, the garages had essentially a free license to make any repairs they deemed necessary. If repair costs would exceed $75 for a given vehicle, the repair men were required to contact study personnel for permission to proceed. A summary of the average costs for Idle test is given in Table 6-29.

Table 6-29. AVERAGE IDLE TEST REPAIR COSTS IN DOLLARS

Service Phase	Controlled (24)	Uncontrolled (31)	All Vehicles (55)
After All Service			
Parts	15.96	12.63	14.08
Labor	17.92	26.83	22.94
Total	33.88	39.46	37.02
After First Service			
Parts	11.95	10.37	11.06
Labor	13.66	18.05	16.13
Total	25.61	28.42	27.19

The higher labor cost for uncontrolled vehicles represents additional diagnosis to locate the source of failure and the fact that four valve jobs were performed versus one valve job for the controlled vehicle group. The valve jobs represent a high labor cost. Not readily apparent is the higher parts incurred by the controlled vehicle set. Two of the 24 controlled cars serviced accounted for $164.47 in parts, including a new carburetor and an air injection reactor pump.

A significant increase in average cost was incurred when vehicles failed the emission retest and were returned to the garage for additional service. Two returned uncontrolled vehicles and one returned controlled vehicle subsequently received valve jobs, and a large number of vehicles received carburetor overhauls and major ignition tuneups.

As a result of the Idle test group of vehicles services, the car owner would expect to be faced with a range of repair cost averages of $27.19 (the first service cost) to $37.02, if additional service were, in fact, warranted.

6.5.3 Key Mode Test Repair Cost

The repairs performed on cars exceeding the passing Key Mode emission test limits were to follow the procedures presented in the Clayton Manufacturing Company's Key Mode Truth Chart Manual. All participating garages were briefed on how to interpret these truth charts and were given copies of the manual. Each car dispatched for service was accompanied by a Key Mode "report card" stating the emission test results with rejected modes indicated.

In spite of this guidance, some garages chose to do more work than was warranted, while a very few did less work than was necessary. Four of the 22 controlled vehicles were returned for additional service while 14 of 42 uncontrolled vehicles were returned. Only one uncontrolled vehicle was found to be in need of a valve job. Nearly all returns were due to carburetor malfunctions, some requiring overhauls, and some with additional adjusting requirements.

The additional service accounted for a 13.6 percent increase in cost for the group as a whole. The average cost of repairs resulting from one service was $24.86. Additional service brought this average up to $28.24. These costs are shown in Table 6-30.

6.5.4 Diagnostic Test Repair Cost

Section 5 indicated that the vehicles obtaining service under the Diagnostic test regime as of 1 May 1971 comprised the "cleanest" group of controlled cars and the "dirtiest" group of uncontrolled cars. The costs necessary to bring the cars down to an acceptable value bear this out in an unusual sense (Table 6-31). The uncontrolled group needed much repair including five valve jobs and four carburetor replacements. The controlled group, on the other hand, had problems that were very difficult to identify and that led to trial and error repairs not necessarily needed to lower the emission level. It was found that repair instructions following detailed diagnosis included replacement of marginal parts that were not considered bad enough to elevate the emission level.

With all service performed, the average cost to the vehicle owner would have been $47.48. The average cost after only one service was considerably lower at $33.29.

Table 6-30. AVERAGE KEY MODE TEST REPAIR COSTS IN DOLLARS

Service Phase	Controlled (22)	Uncontrolled (42)	All Vehicles (64)
After All Service			
Parts	10.98	10.54	10.69
Labor	14.86	18.96	17.55
Total	25.84	29.50	28.24
After First Service			
Parts	9.03	9.65	9.44
Labor	12.51	16.95	15.42
Total	21.54	26.60	24.86

Table 6-31. AVERAGE DIAGNOSTIC TEST REPAIR COSTS IN DOLLARS

Service Phase	Controlled (19)	Uncontrolled (49)	All Vehicles (68)
After All Service			
Parts	14.87	23.34	20.97
Labor	12.54	31.93	26.51
Total	27.41	55.27	47.48
After First Service			
Parts	11.20	17.02	15.39
Labor	10.26	20.86	17.90
Total	21.46	37.89	33.29

6.5.5 Comparison of Vehicle Owner Cost by Test Regime

The preceding paragraphs have presented the average repair costs for each of the four test regimes. A comparison of these costs will be discussed here.

A tabular presentation of the parts and labor costs is given in Table 6-32 with the totals given in Table 6-33. The order by increasing cost, considering all vehicles in each test regime, is Certificate of Compliance ($8.31), Key Mode ($28.24), Idle ($37.02), and Diagnostic ($47.48). Although the magnitudes drop considerably when only first service is considered, the order is not changed.

Table 6-32. AVERAGE SERVICE COST BY TEST REGIME (PARTS AND LABOR) IN DOLLARS

Vehicle Group Test Regimes		After All Service		After First Service		Cost of Additional Service	
		Parts	Labor	Parts	Labor	Parts	Labor
CONTROLLED							
C of C	(61)	1.30	7.62	1.07	7.10	0.23	0.52
Idle	(24)	15.96	17.92	11.95	13.66	4.01	4.26
Key Mode	(22)	10.98	14.86	9.03	12.51	1.95	2.35
Diagnostic	(19)	14.87	12.54	11.20	10.26	3.67	2.28
UNCONTROLLED							
C of C	(64)	1.09	6.64	1.06	6.56	0.03	0.08
Idle	(31)	12.63	26.83	10.37	18.05	2.26	8.78
Key Mode	(42)	10.54	18.96	9.65	16.95	0.89	2.01
Diagnostic	(49)	23.34	31.93	17.02	20.86	6.32	11.06
ALL VEHICLES							
C of C	(125)	1.19	7.12	1.06	6.82	0.03	0.30
Idle	(55)	14.08	22.94	11.06	16.13	3.02	6.81
Key Mode	(64)	10.69	17.55	9.44	15.42	1.25	2.13
Diagnostic	(68)	20.97	26.51	15.39	17.90	5.58	8.60

The subset of uncontrolled cars showed the same ordering as the total set in each test regime but with a much higher dispersion in the case of Diagnostic. The comparison of first service to all service in the cases of Idle and Diagnostic shows the large average increase due to valve jobs and replacement of carburetors.

The controlled vehicle group did show a reordering in average costs for all service with Idle and Diagnostic changing places, Idle becoming highest in cost because of one valve job. Considering first service only, the order becomes Certificate of Compliance, Diagnostic, Key Mode, and Idle with no significant difference between Diagnostic and Key Mode.

Figures 6-12 through 6-15 show the distribution of service costs in $10 range increments to $50, $25 ranges to $100, and those above $100 after first service (A) and after all service (B). The dashed envelope through the peaks is for visual aid only and does not represent a continuous function.

Table 6-33. AVERAGE SERVICE COST BY TEST REGIME (TOTALS) IN DOLLARS

Vehicle Group Test Regimes		After All Service	After First Service	Cost of Additional Service
CONTROLLED				
C of C	(61)	8.92	8.16	0.76
Idle	(24)	33.88	25.62	8.26
Key Mode	(22)	25.84	21.54	4.30
Diagnostic	(19)	27.41	21.46	5.95
UNCONTROLLED				
C of C	(64)	7.73	7.61	0.12
Idle	(31)	39.46	28.41	11.04
Key Mode	(42)	29.50	26.60	2.90
Diagnostic	(49)	55.27	37.89	17.38
ALL VEHICLES				
C of C	(125)	8.31	7.88	0.43
Idle	(55)	37.02	27.19	9.83
Key Mode	(64)	28.24	24.86	3.38
Diagnostic	(68)	47.48	33.29	14.18

Certificate of Compliance shows no significant shift in the cost distribution from first to all service. One carburetor overhaul was necessary as a second service in an attempt to obtain certification. The Idle cost distributions show a shift from the $10 range to $100+ range and are, in fact, valve jobs and major engine repairs performed after an initial attempt to adjust the emission level downward. The shift in distribution in the Key Mode test regime from the low ranges to the mid-ranges generally represents a shift from carburetor adjustments to carburetor overhaul. The one increase to $100 was the addition of a carburetor overhaul to a complete ignition tuneup. The Diagnostic distributions represent not only a shift to valve jobs from both low and mid-ranges but, with the addition of major tuneups in place of minor tuneups, for a general cost shift upward.

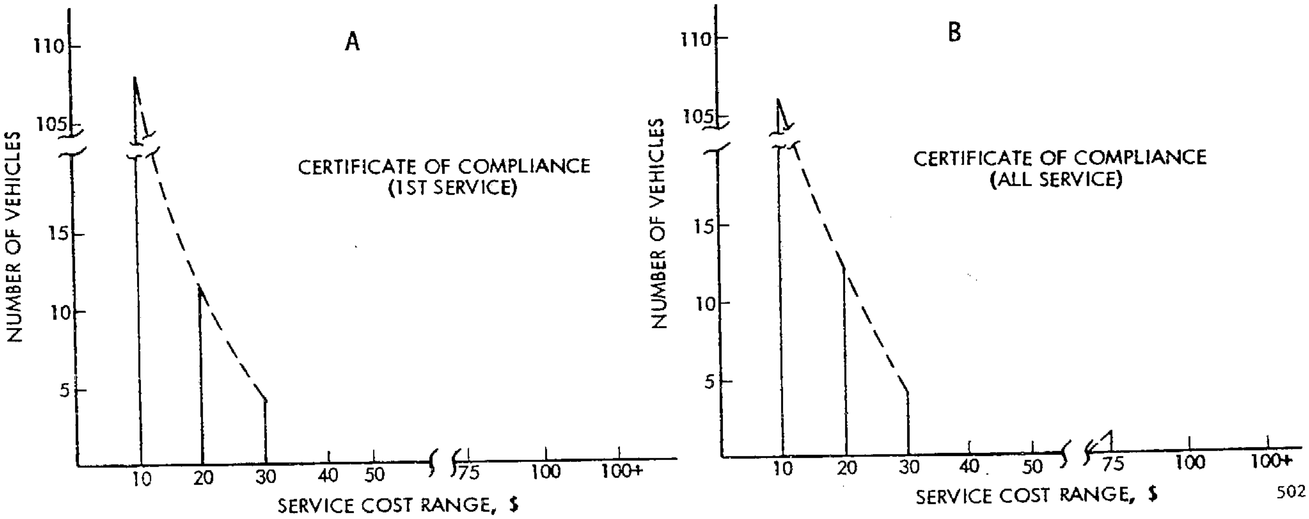

Figure 6-12. CERTIFICATE OF COMPLIANCE SERVICE COST DISTRIBUTION

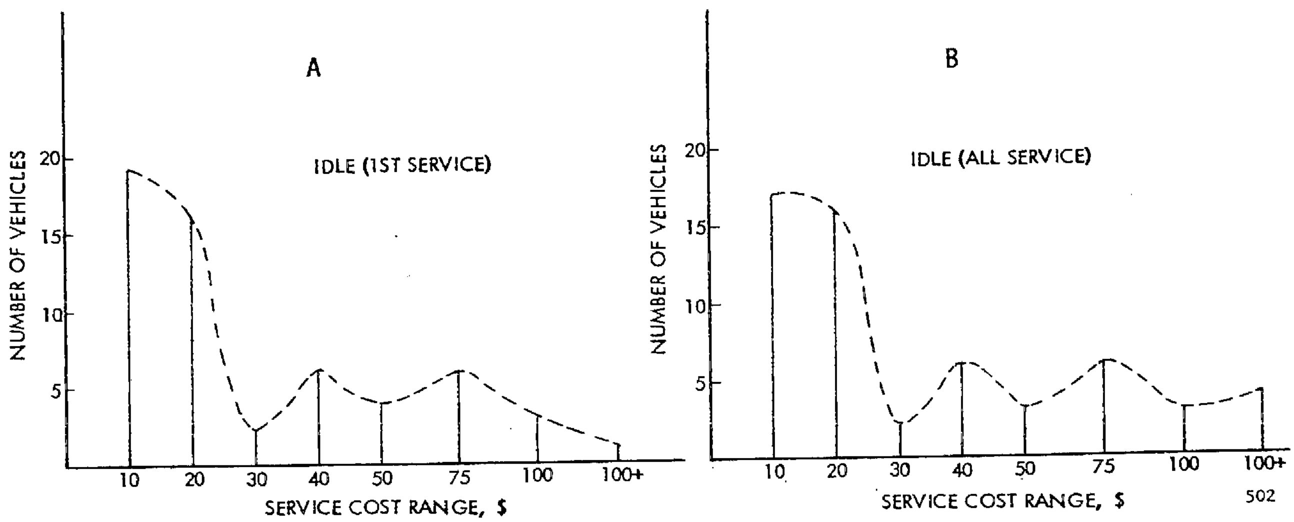

Figure 6-13. IDLE SERVICE COST DISTRIBUTION

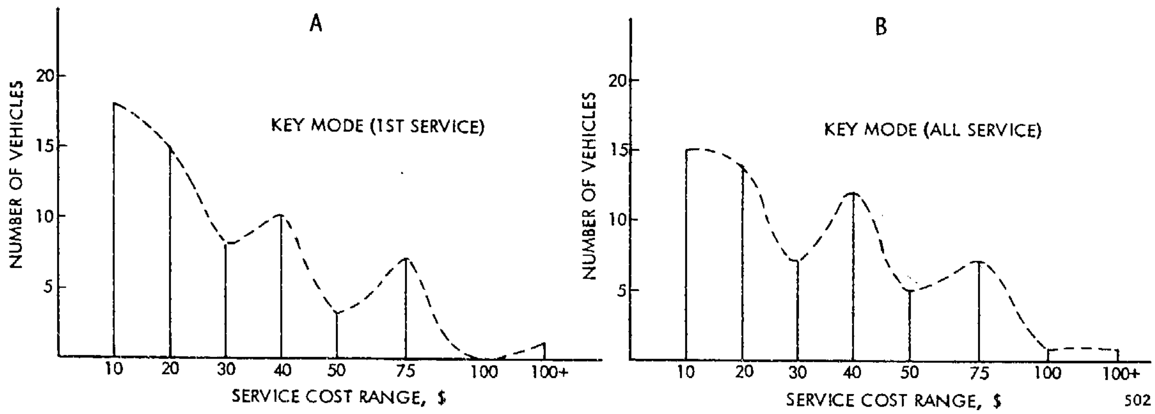

Figure 6-14. KEY MODE SERVICE COST DISTRIBUTION

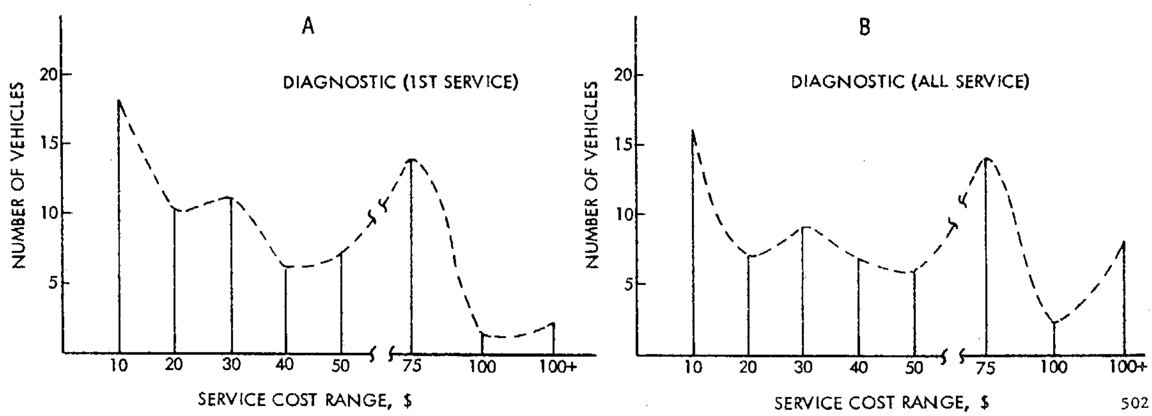

Figure 6-15. DIAGNOSTIC SERVICE COST DISTRIBUTION

6.6 COST MODEL MATHEMATICAL STRUCTURE

This section presents the mathematical relations employed in the Life-Cycle Program Cost analysis model described in paragraph 6.2.

6.6.1 Acquisition and Investments Submodel

In the following paragraphs, the mathematical relationships developed to quantify and manipulate the Investment Cost elements identified are presented

a. Site Acquisition Costs

$$SA = \sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} A_{ij} \overline{ULC}_j \epsilon_{ijs} \delta_{ije}$$

where:

N_g = Number of district geographic divisions within the State selected for implementation (the State's eleven Air Basins were used as the geographic units of analysis throughout the model)

Ns_j = Number of stations in geographic division j

A_{ij} = Area of inspection site i in geographic division j

$\overline{ULC}_j$ = Mean cost of unit area of appropriately zoned land in geographic division j, in dollars

ϵ_{ijs} = Summation variable defined as follows:

$$\epsilon_{ijs} \begin{cases} = 1 \text{ if inspection facility i in geographic division j is stationary} \\ = 0 \text{ if facility i in division j is mobile} \end{cases}$$

δ_{ije} = Summation variable defined as follows:

$$\delta_{ije} \begin{cases} = 1 \text{ if facility (ij) is not a currently existing facility which may be altered for use in periodic vehicle inspection} \\ = 0 \text{ if site (ij) exists and may be altered for use or used immediately with only equipment additions.} \end{cases}$$

b. Facility Construction Costs

$$FC = \sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} AF_{ij} \overline{UCC}_j \epsilon_{ijs} \delta_{ije}$$

where:

AF_{ij} = The area of facility (ij)

$\overline{UCC}_j$ = Unit area construction cost in area j, in dollars

c. Equipment Acquisition and Installation Costs

$$EA = \sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} \sum_{k=1}^{ST} IECS_{ijk}\, \epsilon_{ijs}\, \delta_{ije} + IECM_{ijk}\, \epsilon_{ijm}$$

$$EI = \sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} \sum_{k=1}^{ST} EIC_{ijk}\, \epsilon_{ijs}$$

where:

ST = Number of stationary or mobile inspection facility types

$IECS_{ijk}$ = Initial cost of equipment for stationary facility i in area j that is of type k in dollars

$IECM_{ijk}$ = Initial cost of equipment for mobile facility i in area j of type k, in dollars

ϵ_{ijm} = Summation variable defined as follows:

$$\epsilon_{ijm} \begin{cases} = 1 \text{ if facility i in area j is mobile} \\ = 0 \text{ otherwise} \end{cases}$$

EIC_{ijk} = The cost of installing equipment in station i, area j, that is of type k.

These equipment-related costs are composed of subordinate elements as follows:

$$IECS_{ijk} = IECSI_{ijk} + IECSS_{ijk} + IECAS_{ijk}$$

$$IECM_{ijk} = IECMI_{ijk} + IECMS_{ijk} + IECAM_{ijk}$$

where:

$IECSI_{ijk}$, $IECMI_{ijk}$ = Initial cost of inspection equipment for stationary or mobile facility (ijk) respectively, in dollars

$IECSS_{ijk}$, $IECMS_{ijk}$ = Initial cost of inspection-support equipment for stationary or mobile facility (ijk) respectively, in dollars

$IECAS_{ijk}$, $IECAM_{ijk}$ = Initial cost of station-administrative support equipment for stationary or mobile facility (ijk) respectively, in dollars.

d. Initial Personnel Training and Indoctrination

$$TI = CTI + CTR + IIC + RIC$$

where:

CTI = Inspection-facility personnel salaries paid during training, in dollars

CTR = Repair personnel salaries paid during training, in dollars

IIC = Inspection instruction materials, in dollars

RIC = Repair instruction materials, in dollars

The analysis indicates these categories may again be further resolved into constituent elements:

$$CTI = \sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} \sum_{k=1}^{NTI} IPT_{ijk} \; HI_{jk} \; CHI_k$$

$$CTR = \sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} \sum_{k=1}^{NTR} RPT_{ijk} \; HR_{jk} \; CHR_k$$

where:

NTI, NTR = Number of types of personnel receiving inspection or repair respectively

N_g = Number of geographical divisions

Ns_j = Number of stations in geographical division j

IPT_{ijk} = Number of type-k individuals receiving inspection training for station i in area j

HI_{jk} = Hourly wage rate, including fringe benefits, of inspection station employee type-k in geographic area j, in dollars

CHI_k = Number of total hours per trainee of type-k spent in classroom situation

RPT_{ijk} = Number of individuals of type-k receiving repair-oriented instruction

HR_{jk} = Hourly wage rate, including fringe benefits, of repair personnel of type-k receiving repair-oriented training, in dollars

CHR_k = Total number of hours spent in classroom situation by type-k repair trainee

ICC and RIC involve instructors and classroom facilities, as well as demonstration equipment. Assume sufficient space exists to conduct training programs in completed but as yet nonoperational inspection facilities. In densely populated areas, much more efficient use of instructors may be made, since trainees for several surrounding stations could receive instruction simultaneously.

ICC and RIC each consist of instructor's salaries and classroom facilities. If inspection stations are used as classrooms, the cost of classrooms is limited to simple maintenance and utilities used during the sessions. These costs are assumed to be negligible.

The number of instructors required is given by:

$$\text{Inspection Instructors } N_I = \frac{\sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} \sum_{k=1}^{IT} IPT_{ijk}}{C_I}$$

$$\text{Repair Instructors } N_R = \frac{\sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} \sum_{k=1}^{IT} RPT_{ijk}}{C_R}$$

where:

IT = The number of different training types

C_I, C_R = Number of courses one instructor can administer concurrently (C_I = inspection, C_R = repair)

RPT_{ijk}, IPT_{ijk}, and C_{HR_k} are as previously defined.

If each of these instructors receives a fee per course taught of IR and II, including fringe benefits, for repair and inspection instructors respectively, training and indoctrination costs may be expressed as follows:

$$TI = CTI + CTR + II \times N_I C_I + IR \times N_R C_R.$$

e. Station Qualification and Certification Costs

The previously undefined variables utilized in this and subsequent discussions are identified as follows:

N_{CT} = Number of certification teams required (total program)

N = Number of inspectors required per team

N_{CTj} = Number of inspection teams required in area j

T_{I_k} = Mean time required to inspect 1 k-type station (working days)

TT = Mean travel time allowed between stations (working days)

TQC = Total allowed time for certification of stations (working days)

$EEQC$ = Cost of one complement of test equipment to certify inspection equipment, in dollars

$APQC_k$ = Number of program administrative personnel of type-k required for qualification and certification

$APQCW_{jk}$ = Daily wage rate, including fringe benefits, or certification administrative personnel of type-k in area j, in dollars

QCW_j = Daily wage rate, including fringe benefits, or certification field personnel in area j, in dollars

TC_j = Daily transportation allowance for certification field personnel in area j, in dollars

OS_j = Annual cost of office space per unit area in area j, in dollars

A_{AOj} = Area of office required in area j, in square feet

AT = Number of different types of program administrative personnel

W = Number of working days in one year

OM_j = Investment cost in office machines and supplies per administrative office in area j, in dollars

N_j = Number of administrative offices in area j

$[\alpha]_{INT}$ = Next larger integer value of α

Considering first the field cost of inspection-station certification personnel, the number of certification teams composed of one or more individuals required to certify the complement of inspection an/or repair centers may be expressed as follows:

$$N_{CT} = \sum_{j=1}^{N_g} \left[\frac{\sum_{i=1}^{N_{sj}} \sum_{k=1}^{ST} (TI_k + TT)\, \epsilon_{ijs}}{TQC} \right]_{INT}$$

Note that the calculation of inspection teams excludes mobile sites from consideration. It is assumed that for mobile sites (if any are required), either operating personnel will be capable of certifying them, or one team will certify them prior to program commencement when they would be dispatched to their assigned areas.

The cost of these inspection teams may be represented as follows:

$$\sum_{j=1}^{N_g} N_{CT_j}\, NTQC(QCW_j + TC_j) + N_{CT_j}\, EEQC$$

Substituting into the previously described expression for field costs,

$$\text{Field Costs} = \sum_{j=1}^{N_g} \left[\frac{\sum_{i=1}^{Ns_j} \sum_{k=1}^{ST} (T_{I_k} + TT)\ \epsilon_{ijs}}{TQC} \right]_{INT} \left[NTQC(QCW_j + TC_j) + EEQC \right]$$

Administrative costs of certification are simply the salaries of program administrative personnel and costs of office operations during the certification period. It is assumed that this same personnel staff will be required for certification as well as for the administration of the program throughout its life cycle. Administrative costs of certification are represented as follows:

$$\text{Administrative Costs} = \sum_{j=1}^{N_g} \sum_{i=1}^{N_j} \left[(A_{AO_j}\ O_{S_j}\ TQC/W) + OM_j + \sum_{k=1}^{AT} APQCW_{jk}\ APQC_k \times TQC \right]$$

The summation of the individual cost constituents will provide the total required acquisition and investment costs for a given test regime.

$$\begin{aligned} C_{INV} = PB &+ \sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} \left\{ (A_{ij}\ \overline{ULC}_j + AF_{ij}\ \overline{UCC}_j + \sum_{k=1}^{ST} IECS_{ijk})\ \epsilon_{ijs}\ \delta_{ije} \right. \\ &+ \sum_{k=1}^{ST} \left[(IECM_{ijk}\ \epsilon_{ijm} + EIC_{ijk}\ \epsilon_{ijs}) \right. \\ &\left. + (IPT_{ik}\ HI_{jk}\ C_{HI_k} + RPT_{ik}\ HR_{jk}\ C_{HR_k}) \right] \\ &\left. + \frac{II \sum_{k=1}^{IT} IPT_{ik}}{S_I} + \frac{IR \sum_{k=1}^{IT} RPT_{ik}}{S_R} \right\} \\ &+ \sum_{j=1}^{N_g} \left[\frac{\sum_{i=1}^{Ns_j} \sum_{k=1}^{ST} (T_{I_k} + TT)\ \epsilon_{ijs}}{TQC} \right]_{INT} \left[NTQC\ (QCW_j + TC_j) + EEQC \right] \\ &+ \sum_{j=1}^{N_g} \sum_{i=1}^{N_j} \left[(A_{AO_j}\ O_{S_j}\ TQC/W) + OM_j + \sum_{k=1}^{AT} APQCW_{jk}\ APQC_k \times TQC \right] \end{aligned}$$

6.6.2 Operations and Maintenance Submodel

In the following paragraphs, the mathematical cost relationships are developed for each of the cost elements discussed above.

a. Facility Personnel Salaries

Inspection Personnel

$$S_{IP} = \sum_{j=1}^{Ng} \sum_{i=1}^{Ns_j} \sum_{k=1}^{IP_{ij}} IP_{ijk}\, PRS_{jk}\, HS_{ijk}\, \epsilon_{ijs}\, \delta_{ije}$$

$$+ IP_{ijk}\, PRM_{jk}\, HM_{ijk}\, \epsilon_{ijm}\, \delta_{ije}$$

where:

IP_{ij} = Number of inspection personnel types required for inspection facility (ij)

IP_{ijk} = Number of inspection personnel of type-k required by facility (ij)

PRS_{jk} or PRM_{jk} = The hourly rate of pay including fringe benefits for each inspector of type-k at stationary or mobile facility, respectively, in area j, in dollars

HS_{ijk} or HM_{ijk} = Number of hours worked annually by an inspector of type-k at stationary or mobile facility (ij), respectively

Station Administrative Personnel

The expression for these costs closely parallels that of inspection personnel. Allowance is made for varying categories of personnel performing administrative functions.

$$S_{AP} = \sum_{j=1}^{N_g} \sum_{i=1}^{Ns_j} \sum_{k=1}^{ISAP_{ij}} ISAP_{ijk}\, PRSAP_{jk}\, HS_{ijk}\, \epsilon_{ijs}\, \delta_{ije}$$

$$+ ISAP_{ijk}\, PRMAP_{jk}\, HM_{ijk}\, \epsilon_{ijm}\, \delta_{ije}$$

where:

$ISAP_{ij}$ = Number of types of inspection station administrative personnel required for station (ij)

$ISAP_{ijk}$ = Number of station administrative personnel of type k required at station site (ij)

$PRMAP_{jk}$ = Hourly wage rage including fringe benefits of mobile facility administrator of type-k in area j, in dollars

$PRSAP_{jk}$ = Hourly wage rate including fringe benefits for stationary-site administrative personnel of type-k, in area j, in dollars

HS_{ijk} and HM_{ijk} = Hours worked annually by station administrative personnel of type-k in stationary and mobile sites, respectively.

b. <u>Equipment Maintenance Costs</u>

Maintenance equipment costs directly attributable to inspection equipment involve the actual service time of a given equipment, and the individual parts, modules, or equipments replaced. It is assumed that individuals other than inspection-station personnel will usually be required to perform corrective maintenance on equipments. The annual direct cost of equipment maintenance expressed in dollars is given by:

$$M_{EI} = \sum_{j=1}^{Ng} \sum_{i=1}^{Ns_j} \sum_{k=1}^{ET} \sum_{L=1}^{N_k} MACM_k \, NE_{ik} + MW_{jk} \, MTTR_k \, NE_{ik} \times \frac{1}{MTBF_k}$$

$$+ NS_{kL} \, SP_{kL}$$

where:

N_k = Number of types of line-replaceable spares for equipment of type-k

$MACM_k$ = Mean cost of annual maintenance of one type-k equipment, in dollars (includes cost of spares)

NE_{ik} = Number of equipments of type-k in station i

MW_{jk} = Hourly wage, including fringe benefits, of maintenance personnel of equipment type-k in area j, in dollars

$MTTR_k$ = Mean time to repair a type-k equipment, in hours

$MTBF_k$ = Mean time between failures of type-k equipment, in years

NS_{kL} = Number of type-L spares for type-k equipment ordered annually

SP_{kL} = Cost per type-L spare for type-k equipment, in collars

In the instrumentation survey conducted earlier in the study phase, maintenance support information was solicited from equipment suppliers. Rarely was this type of data provided. Reliability and maintainability data are apparently nonexistent for this type of instruments. Perhaps these suppliers are unaccustomed to purchasers desiring such data and consequently have not instituted programs to derive and demonstrate these information factors that are essential to quantifying and establishing logistics support. In view of the data deficiencies, it is necessary to determine maintenance costs on a cost-estimating relationship. That is, for prime equipments directly related to emission inspection, a fixed percentage of the applicable investment cost would be allocated or assessed for annual operation cost.

d. Inspection-Support Equipments and Supplies Cost

$$M_{ES} = \sum_{j=1}^{Ng} \sum_{i=1}^{Ns_j} \sum_{k=1}^{ET} \sum_{L=1}^{NET} N_{kL}\ CSQ_{kL}$$

where:

N_{kL} = Number of support-equipment elements of type-L for support equipment or prime equipment of type-k required annually.

CSQ_{kL} = Cost of one such unit, in dollars

Other variables are previously defined.

e. Administrative Support Equipments and Supplies Cost

These maintenance costs involve office equipment and clerical supplies replaced and will be evaluated at a fixed percentage of initial investment cost.

f. Facility Maintenance

This category includes items such as utilities, taxes, and building and grounds maintenance. These items are calculated separately, or in the case of taxes and building maintenance, a given percentage of investment cost is determined from historical data of similarly operated facilities.

g. Program Management and Administration

Administrative Personnel - This category involves executive and management, station monitoring, and clerical support personnel. A model of these costs may be formulated as follows:

$$AP = \sum_{j=1}^{Ng} \sum_{k=1}^{N_j} Nap_{jk}\ Sa_{jk}$$

where:

N_j = Number of administrative levels in area j

Nap_{jk} = Number of administrative personnel of level k in area j

Sa_{jk} = Annual salary, including fringe benefits, of administrative personnel of level k in area j, in dollars

This abstract statement of administrative personnel costs allows maximum flexibility in structuring the administration of any of the diverse test regimes, and at the same time provides a complete accounting of costs. It includes periodic monitoring of inspection/repair facilities as well as clerical tasks.

Office Space and Supplies - These costs are the annual costs of operating administrative offices of determined size and number and follow closely the pattern established during the certification phase. It is assumed that similar costs incurred during certification will be incurred throughout the life cycle of the program. They are expressed by the following formulation:

$$A_{OS} + A_{ES} = \sum_{j=1}^{Ng} \sum_{i=1}^{N_j} (A_{AO_j}\, O_{S_j}) + A_{ES_j}$$

where:

A_{ES_j} = Mean cost of supplies annually per administrative office in area j.

All other variables are as previously defined.

The summation of the individual operating and maintenance cost elements will provide the total test regime program operations costs, as shown below.

$$C_{op_n} = \sum_{j=1}^{Ng} \sum_{i=1}^{Ns_j} Ke^n \Bigg[\sum_{k=1}^{IP_{ij}} (IP_{ijk}\, PRS_{jk}\, HS_{ijk}\, \epsilon_{ijs}\, \delta_{ije}$$

$$+ IP_{ijk}\, PRM_{jk}\, HM_{ijk}\, \epsilon_{ijm}\, \delta_{ije})$$

$$+ \sum_{k=1}^{ISAP_{ij}} ISAP_{ijk}\, PRSAP_{jk}\, HS_{ijk}\, \epsilon_{ijs}\, \delta_{ije}$$

$$+ ISAP_{ijk}\, PRMAP_{jk}\, HM_{ijk}\, \epsilon_{ijm}\, \delta_{ije}$$

$$+ \sum_{k=1}^{ET} \Bigg(\sum_{L=1}^{Nk} MACM_k\, NE_{ik} + MW_{jk}\, MTTR_k\, NE_{ik} \times \frac{1}{MTBF_k}$$

$$+ N_{kL}\; SP_{kL} + \sum_{L=1}^{NET} N_{kL} CSQ_{kL} \Bigg) \Bigg] + Ke^n \sum_{j=1}^{Ng} \sum_{k=1}^{Nj} Nap_{jk}\, S_{a_{jk}}$$

$$+ A_{AO_j}\, O_{S_j} + A_{ES_j}$$

The total life cycle cost of the test regime for a given operational duration will be the summation of the research and development, acquisition and investment, and operation and maintenance costs categories as shown below.

$$
\begin{aligned}
LCC = \sum_{n=1}^{Y} \Bigg[& C_{RD} + PB + \sum_{j=1}^{Ng} \sum_{i=1}^{Ns_j} (A_{ij}\, \overline{ULC}_j + AF_{ij}\, \overline{UCC}_j \\
& + \sum_{k=1}^{ST} IECS_{ijk})\, \epsilon_{ijs}\, \delta_{ije} + \sum_{k=1}^{ST} \Big[(IECM_{ijk}\, \epsilon_{ijm} + EIC_{ijk}\, \epsilon_{ijs}) \\
& + (IPT_{ik}\, HI_{jk}\, C_{HI_k} + RPT_{ik}\, HR_{jk}\, C_{HR_k}) \Big] \\
& + \frac{II \sum_{k=1}^{IT} IPT_{ik}}{S_I} + \frac{IR \sum_{k=1}^{IT} RPT_{ik}}{S_R} \\
& + \sum_{j=1}^{Ng} \left[\frac{\sum_{i=1}^{Ns_j} \sum_{k=1}^{ST} (T_{I_k} + TT)\, \epsilon_{ijs}}{TQC} \right]_{INT} \Big[NTQC(QCW_j + TC_j) + EEQC \Big] \\
& + \sum_{j=1}^{Ng} \sum_{i=1}^{N_j} \Big[(A_{AO_j}\, O_{S_j}\, TQC/W) + OM_j + \sum_{k=1}^{AT} APQCW_{jk}\, APQC_k \times TQC \Big] \\
& + \sum_{j=1}^{Ng} \sum_{i=1}^{Ns_j} Kc^n \Bigg[\sum_{k=1}^{IP_{ij}} (IP_{ijk}\, PRS_{jk}\, HS_{ijk}\, \epsilon_{ijs}\, \delta_{ije} \\
& + IP_{ijk}\, PRM_{jk}\, HM_{ijk}\, \epsilon_{ijm}\, \delta_{ije} \\
& + \sum_{k=1}^{ISAP_{ij}} ISAP_{ijk}\, PRSAP_{jk}\, HS_{ijk}\, \epsilon_{ijs}\, \delta_{ije} \\
& + ISAP_{ijk}\, PRMAP_{jk}\, HM_{ijk}\, \epsilon_{ijm}\, \delta_{ije}
\end{aligned}
$$

$$+ \sum_{k=1}^{ET} \left(\sum_{L=1}^{N_k} MACM_k \quad NE_{ik} + MW_{jk} \; MTTR_k \frac{1}{MTBF_k} \right.$$

$$\left. \left. + NS_{kL} \; SP_{kL} + \sum_{i=1}^{N_{ET}} N_{kL} \; CSQ_{kL} \right) \right]$$

$$\left. + Ke^n \sum_{j=1}^{Ng} \sum_{k=1}^{N_j} Nap_{jk} \; Sa_{jk} + A_{AO_j} \; O_{S_j} + A_{ES_j} \right]$$

A computer program was written to facilitate utilization of the foregoing model. An IBM System 360, Model 65 digital computer was used to perform all cost calculations whose results are presented for each regime beginning with paragraph 6.3.2. Costs are calculated by air basin and are segregated according to investment and operating cost per air basin. A discussion of research and development costs is presented in Section 10, Volume II, of this report.

SECTION 7
PUBLIC OPINION SURVEY

The purpose of this survey conducted by Opinion Research of California was to measure opinions of vehicle owners concerning a motor vehicle emission inspection program. A multistaged, modified probability sample design was utilized to select 1000 owners of private passenger automobiles registered in the State of California. The sample design called for stratification of the State into major population areas, with a systematic selection of 100 primary sample clusters which were each factored into 10 subclusters. Ultimate sampling units consisted of eight vehicle owners, one of whom was randomly selected as the original interviewee. The remaining names were randomly substituted if the original interview could not be completed.

The interviewing was conducted by telephone, and two call-backs were made, for a total of three calls, before substitutions were introduced. In those sampling units where no interview could be completed by telephone, the selected respondent was interviewed in person at his place of residence.

A total of 2506 calls were made to complete the 1000 sample. Sixty-two in-home interviews were necessary to meet sample design requirements. Sixty-six percent of the completed sample were original interviewees, while 34 percent were substitutes.

The interviewing was conducted from 13 March 1971 through 22 March 1971. Additionally, an investigation of attitudes among a selected group of 50 leaders in California about a vehicle emission inspection program was made by Opinion Research of California. These 50 select individuals are associated with various business, industrial, legal, governmental, news media, employee and public organizations. These individuals were interviewed in person during the period from 26 April 1971 to 30 April 1971.

7.1 METHODOLOGY

Mindful of the purpose of the study and anticipated application of the data obtained, this study was designed to provide a high level of precision and confidence as well as develop in-depth data. The statistical validity (precision and confidence) of all survey results are primarily dependent on the size and design of the sample. In survey research the size of the sample necessary to yield significant results not only relates directly to the number of units (persons) in the universe, but also with the absolute number of cases in the sample. An optimum sample in a survey is one which fulfills the requirements of efficiency, representativeness, reliability and flexibility. The sample should be large enough to avoid intolerable sample error, and small enough to avoid unnecessary expense. It should be large enough, however, to achieve required precision, but not a needlessly high precision.

Applying the above criteria, the survey utilized a sample that yielded a 95 percent degree of certainty and a ± 4 percent precision or permissible error. These sample requirements indicate a sample size of 1000 cases distributed throughout the State of California. The statistically selected sample provided for a representative cross-section of California registered vehicle owners.

In addition to the general investigation of motorists' attitudes, the opinions of special interest groups and/or leaders who may have a direct impact upon the overall acceptance or rejection of the program were assessed. Fifty such individuals are included in this select group (i.e., media representatives, legislative advocates, and automobile associations).

7.2 SUMMARY OF FINDINGS

7.2.1 Objectives

The primary objectives of the public opinion survey were to ascertain the California motoring public's acceptance of a mandatory vehicle emission inspection and maintenance program. Investigation of public attitudes included the following broad subject areas:

a. The advantages/disadvantages of a vehicle emission inspections and maintenance program

b. The convenience/inconvenience factors, including location of inspection centers, frequency of inspection, time allocation for inspection

c. The desirable/undesirable aspects of corrective maintenance as it relates to personal convenience, reduction of vehicle emissions, vehicle safety and operation

d. The acceptance/rejection of cost factors relating to both inspection and corrective maintenance

e. The approval/disapproval of public and/or private operation of the inspection program

f. The acceptance/rejection of punitive measures for nonconformity to the program.

7.2.2 Questionnaire

Opinion Research of California reviewed related research and literature preliminary to drafting the questionnaire document. Questionnaire conferences were held with representatives of the Air Resources Board and Northrop Corporation to assure maximum data acquisition. The questionnaire was pretested and revised accordingly. A copy of the questionnaire is provided in appendix K.

7.2.3 Results

More than three-fourths of the automobile owners and four out of five of the leaders interviewed in the study name the automobile as the major contributor to air pollution in California at this time. Approximately four out of ten owners interviewed have only one car in the family, an almost equal number have two cars, while the remainder have more than two cars. These vehicles virtually run the gamut of makes and models, with Chevrolet and Ford being the front runners. According to the survey, automobile owners have little knowledge about the type of emission tests made on their vehicle, although more than three-fourths of them maintain they have had the pollution control device in the automobile inspected.

Slightly more than half of the survey respondents maintain they have had their vehicle checked at some time or another by the California Highway Patrol at one of their side-of-the-road safety inspection points. Overall, the safety inspection program is viewed positively by the majority of those interviewed with less than one-fourth of the respondents offering negative comments about the inconvenience or ineffectiveness of the program.

More than half of the leaders also view the program favorably. However, one out of five of these individuals maintain the program should be expanded to detect more defective automobiles, and eight of the leaders maintain the program is not as effective as it should be primarily because it is "hit and miss."

The survey results indicate that three-fourths of the car owners believe a mandatory vehicle emission inspection program for all vehicles in the State is necessary, while just over half of the leaders agree that such a mandatory program is necessary.

The primary advantages of a mandatory vehicle emission inspection program in the car owner's opinion is that it will reduce air pollution, force people to repair their cars, and detect defective automobiles. The leaders also view the advantages of the program as reducing pollution and detecting defective automobiles. Additionally, the leaders believe the program would check the effectiveness of the emission control devices and encourage more technological advances in the area.

The major disadvantages of such a program are the expense and inconvenience, according to the vehicle owner. The leaders see these as disadvantages in addition to the problems of administering a statewide program.

More than half of the car owners believe the inspection program should be conducted by the State of California rather than private garages or service stations licensed by the State, whereas, the reverse is true of the leaders; more than half of these individuals believe the inspections should be conducted by private facilities.

Among the vehicle owners who believe the inspection should be made by the State of California, the main reason is they do not have trust in the private garages and service stations. The main reason the private garage is selected by those who do so is because of the convenience factor.

The leaders who believe the inspections should be conducted by the State are likewise concerned about potential abuses and dishonesty of the private garages, but the main reason for selecting the private garage or station is because of the cost to the State to develop and run the inspection centers.

More than three-fourths of the automobile owners believe that motor vehicles should be checked at least once a year for emissions; three-fifths of the leaders concur with this frequency. Consistent with other results in the Survey, the vast majority of vehicle owners (82 percent) would favor a mandatory vehicle emission inspection program in California. Three out of five of the leaders would also favor such a program.

The principal reason for the respondent's favoring the program is that it will reduce air pollution, and the primary reason for opposing the program is the cost. The majority of the automobile owners interviewed would continue to favor the program if the inspection took 30 minutes or less, if the inspection fee were $1.00 or less, if they had to drive 10 miles or less to an inspection center, and if the average repair costs were $10.00 or less. When the time limit, driving distance and costs exceed those described above, a majority of the respondents would oppose the mandatory vehicle inspection program.

Just over half of the owners interviewed and just less than half of the leaders believe 15 days is a sufficient length of time to repair a car if it does not pass the vehicle emission inspection. Among those who believe 15 days is not a sufficient length of time, the majority maintain 30 days is the minimum number necessary to have a deficient car repaired.

A significant division of opinion exists among both vehicle owners and leaders on the question of enforcement provisions in the inspection program. Forty-seven percent of the owners approve and an equal number disapprove of an enforcement provision which would require the owner to repair his vehicle within a specified time limit or surrender his license plates and registration papers. Nineteen of the leaders approve, and 23 disapprove of the same proposal; the remainder are undecided on the issue. Amont those who disapprove, approximately half believe there should be some fine imposed, but there is no concensus as to the amount of the fine.

A final question asked of the vehicle owners was, "Now that you know more about the mandatory vehicle emissions inspection program, in general, do you approve or disapprove of spending the necessary time and money to reduce vehicle emissions and lessen air pollution in California?" Eighty-six percent of all respondents maintain they would approve of such expenditures of time and money.

SECTION 8
PROGRAM COST-EFFECTIVENESS

This section combines the results of the effectivenss and cost analyses to perform a cost-effectivenss evaluation and comparison of the alternatives. The advantages of State and private industry participation in such a program also are considered. Results of the total analyses lead to a recommended program implementation.

The section begins with the definition and development of a cost-effectiveness (CE) measure. Combining the results of the effectiveness and cost analyses discussed in previous sections, program CE indices are derived for each test regime. These quantitative measures are then used to evaluate and compare the alternatives.

Recognizing that many important considerations cannot be objectively measured or quantified, a qualitative analysis is performed which considers factors such as growth potential, effects of future emissions regulations, and the impact of future technology.

Results of the public opinion surveys also are considered. These will include findings as noted by the statewide survey, and those from the vehicle testing phase. Consideration of the opinions of the vehicle owners prior to the formulation of an implementation program will result in an acceptable program for the majority of the populace.

8.1 MEASURES OF COST EFFECTIVENESS

Simply stated, a CE analysis attempts to identify, define, and quantify the benefits derived for the money spent. As such, it requires an understanding of the functional characteristics of the total program, the physical characteristics of the prime and supporting equipments and systems, the interrelationships and interdependencies of the machines and men, and the objectives and results of implementing such a program. The effectiveness evaluation, discussed in Section 5, relates vehicle testing and maintenance-effects data to the overall program objective of emissions reduction. The cost of resources and funds necessary to equip, staff, operate, and manage the inspection facilities were discussed in Section 6. To conduct the CE analysis, the respective effectiveness measures and corresponding cost implications of each test regine are considered.

In the following paragraphs, the CE index is developed to evaluate and compare the alternatives. For each test regine, a CE index is calculated relative to each operating year to illustrate trends expected during the program duration. An evaluation of the individual trends and a comparison among the test regimes will provide relative measures of CE. These quantitative measures are complemented with a qualitative analysis of uncertainty factors as related to future regulations and technological advancements and their effects on the test regimes being considered.

8.1.1 Development of Cost-Effectiveness Index

In the previous sections of this report, program effectiveness was evaluated in terms of emission reduction achievable per year as a function of test regime. The resource acquisition costs plus operation and maintenance costs per test regime also were evaluated. Thus, although discussed and developed separately, the effectiveness and cost models are not independent. Combining the results of these two models, a CE model is achieved that is simple, computable, and representative of the alternatives. Shown below is the simplified equation to be used for determining the quantitative measures of CE.

$$\text{Cost Effectiveness (CE)} = \frac{\text{Effectiveness Measure}}{\text{Program Cost}} = \frac{\text{Tons of Pollutants}}{\text{Dollars}}$$

Recall that the effectiveness measures were calculated and plotted as a function of program calendar year, beginning in 1972 and projected to 1991. Correspondingly, the program costs were calculated on a yearly basis starting in 1972, assumed to be the initial year of implementation for this analysis. In effect, then, the above CE index, when calculated, would determine the CE of each test regime on an annual basis.

Using the CE indices thus calculated, the alternatives can be ranked in order of greatest emission reduction for money expended. The test regime achieving the greatest reduction for the least estimated total cost would generate the largest index, and would thus rank the highest. This does not necessarily mean that this particular test regime would realize the greatest reduction, nor does it imply that it would cost the least to implement. It merely identifies the one test regime that realizes the greatest potential for a specified amount of resources and money.

8.1.2 Determination of Test Regimes Indices

The CE index for each test regime is calculated for each program year. Based on the yearly effectiveness estimation and the corresponding costs incurred, a ratio of tons emission reduction per dollar spent is calculated. Equal weighting of HC, CO, and NO_x will be used in the effectiveness measures unless otherwise specified. This was selected to reflect actual reduction as a function of cost. It was previously shown in Section 5 that the weighting factors did not alter the ranking.

8.1.3 Evaluation and Comparison of Test Regimes

Facilities for the four test regimes may be owned and operated by the State, private industry, or a combination of the two. In the following paragraphs, the various alternatives will be evaluated and compared, using calculated CE indices as the criteria.

8.1.3.1 State Owned and Operated Inspection Facilities - In this alternative, the State of California acquires the necessary sites, constructs the inspection facilities, equips the test lanes, staffs the facilities, and manages the total program. Figure 8-1 compares the four test regimes, using the calculated CE indices.

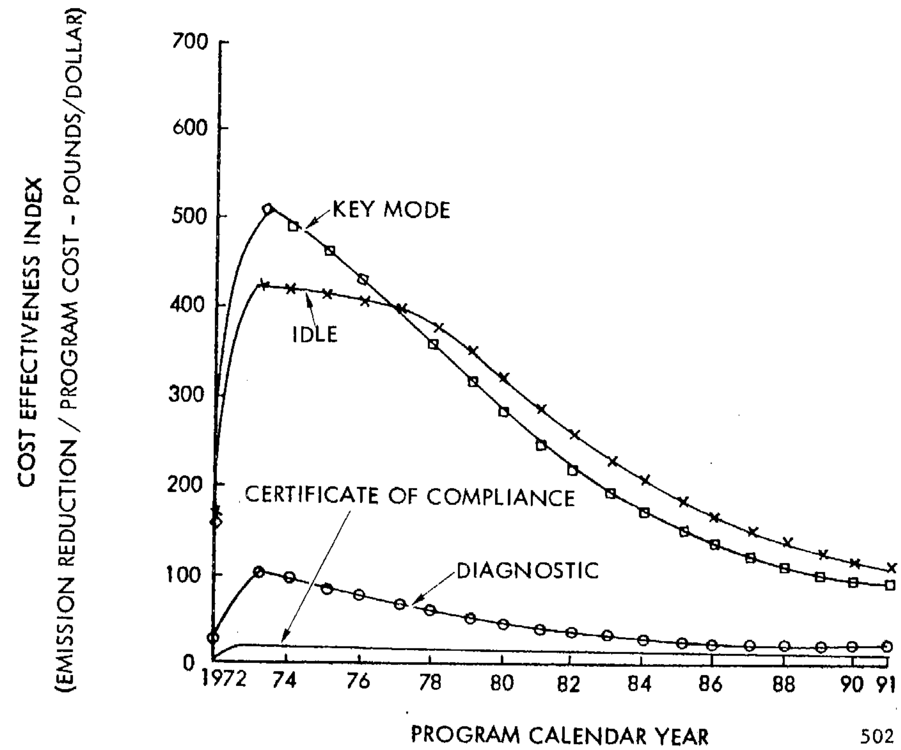

Figure 8-1. TEST REGIMES COMPARISON -
STATE OWNED AND OPERATED INSPECTION FACILITIES

Key Mode test exhibits the greatest emission reduction for the costs incurred during the first 5 years of operation. After that, it is essentially equal to Idle test. The figure shows that Idle test is more cost-effective than Key Mode during the period 1978 through 1991.

Diagnostic test is much lower than both Key Mode and Idle tests. This is due to its high annual operating cost, which is approximately three times greater than either of the top two.

Certificate of Compliance is relatively poor compared with the other three test regimes. This is not surprising, since it achieved relatively little emission reduction, whereas the annual operating costs were about twice that of Idle or Key Mode.

Figure 8-2 shows the CE index as a function of air basins, assuming the Key Mode or Idle test regime is implemented. The purpose of the figure is to indicate the differences that occur based on vehicle population density per air basin. Thus, the most cost-effective air basin to implement would be the South Coast Basin (1), with the least cost-effective being the Great Basin Valleys (11).

The figure considers the pollutants to be equally weighted, with both emission reductions and operating costs based on the 1973 calendar year. Subsequent calendar years would show proportionately less CE on the whole; however, the relative ranking of the air basins would remain the same.

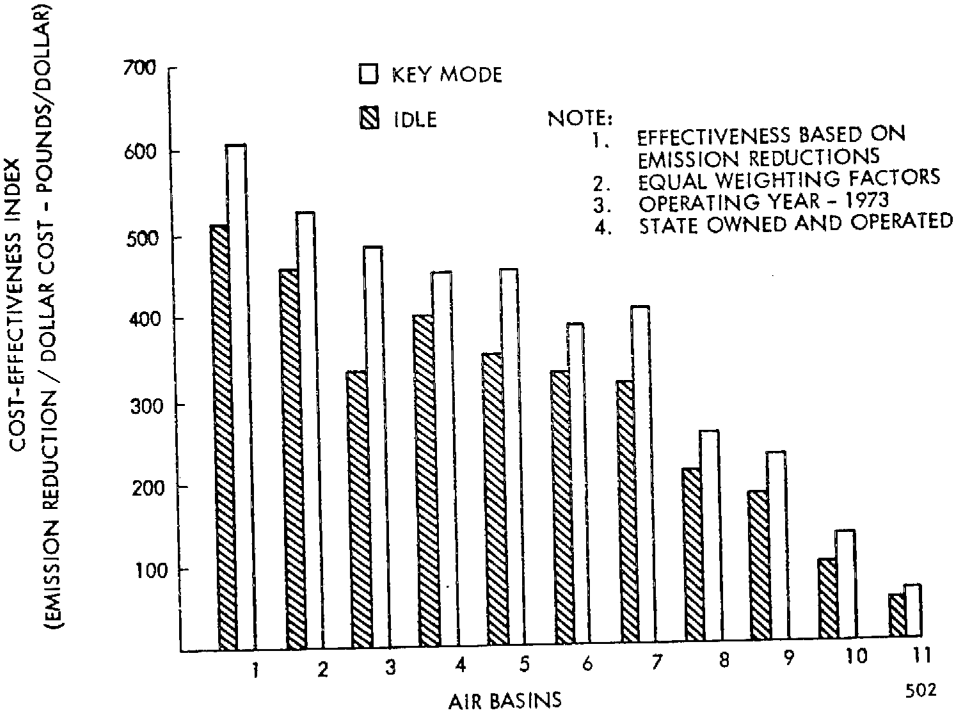

Figure 8-2. COST-EFFECTIVENESS BY AIR BASINS

8.1.3.2 Privately Owned and Operated Inspection Facilities - For this alternative, the State of California will select, on a competitive basis, a private concern to administrate and manage the overall program. This would include site selection and construction of new inspection facilities. The actual ownership and operation of the inspection facilities would be by private industry, subject to the applicable State regulations. It is assumed that a staff of State personnel would be required to review the inspection activities periodically to assure conformity to State-established policies. Cost items would be similar to State ownership and operation, plus the supplemental cost of the State regulatory agency and private industry taxes and profits.

Figure 8-3 shows the CE indices by calendar year for each of the four test regimes. Key Mode test exhibits an early advantage over the other three test regimes. After 5 years of operation, the Idle test regime shows a slight advantage over the Key Mode test.

Both Diagnostic test and Certificate of Compliance are relatively low in CE when compared with the other two test regimes. Whereas Diagnostic test is fairly effective in achieving emission reductions, the high annual operating cost (approximately \$40 million) of the inspection facilities seriously reduces the ratio of emission reduction achieved for each dollar spent. In the case of Certificate of Compliance, the CE index is lowered considerably more due to much lower effectiveness than that achieved by Diagnostic coupled with an annual operating cost of about \$30 million (nonescalated).

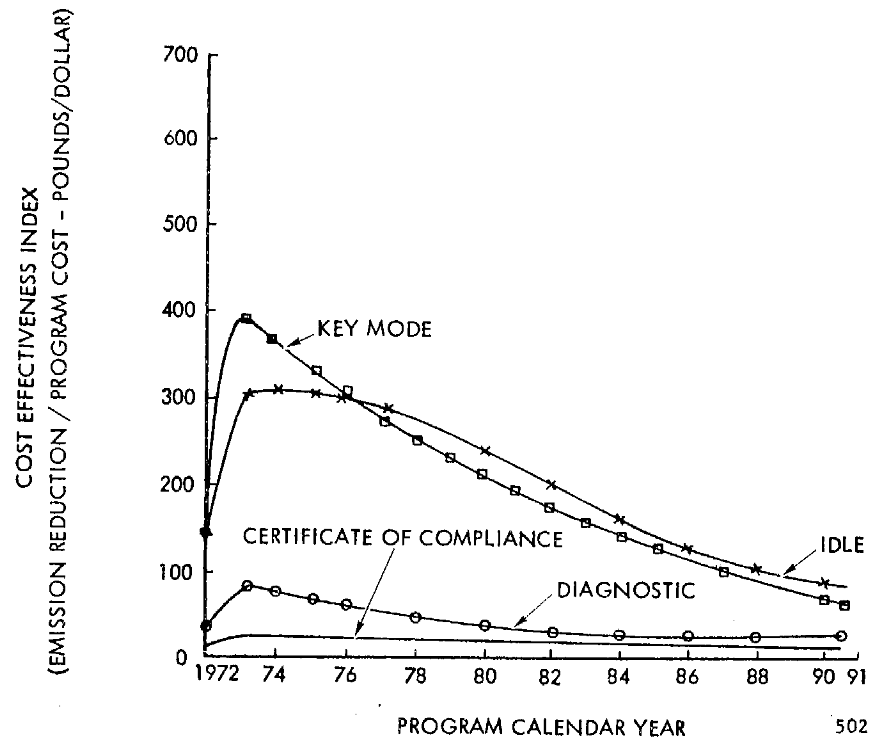

Figure 8-3. TEST REGIMES COMPARISON - PRIVATELY OWNED AND OPERATED

8.1.3.3 State Licensing of Existing Privately Owned Facilities - In this alternative, the State of California would provide total program administration and management. Existing vehicle maintenance centers are qualified and certified by a State agency to perform vehicle emission inspection. Service may or may not be performed on-site.

Many of the investment costs are obviated due to the existence of the facilities. Additional cost considerations included equipment depreciation and business profit. Taxes were not considered, because inspection fees are based on labor charges only.

Figure 8-4 compares the four test regimes as a function of calendar year. Key Mode test exhibits a greater CE index than Idle test during the first 4 years of operation. After 1976 throught 1991, the Idle test regime is better than Key Mode. Diagnostic test and Certificate of Compliance rank third and fourth, respectively, from 1972 and on.

8.1.3.4 Cost-Effectiveness Comparison of Ownership and Operation - Figure 8-5 illustrates the CE of Idle test inspection facilities as a function of ownership and operation. State owned and operated facilities are relatively more cost-effective than either privately owned and operated or State-licensed private facilities. The most obvious reason is that State facilities were designed specifically to do only inspections. Privately owned and operated would be similar to State owned, except for profit margin, taxes, and parallel administrative cost functions as related to program surveillance.

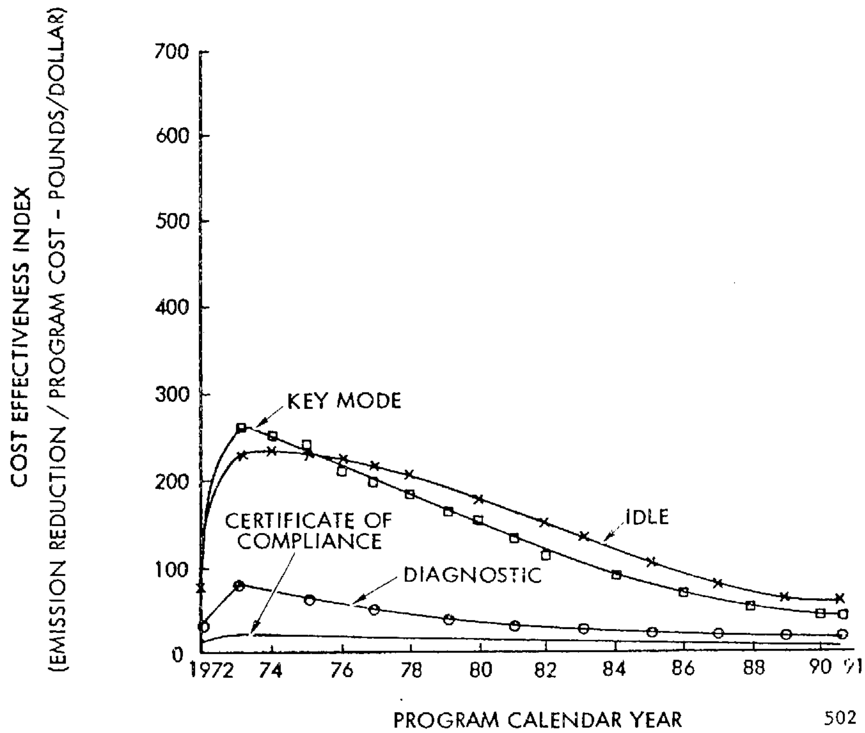

Figure 8-4. TEST REGIMES COMPARISON - STATE LICENSED, EXISTING, PRIVATE FACILITIES

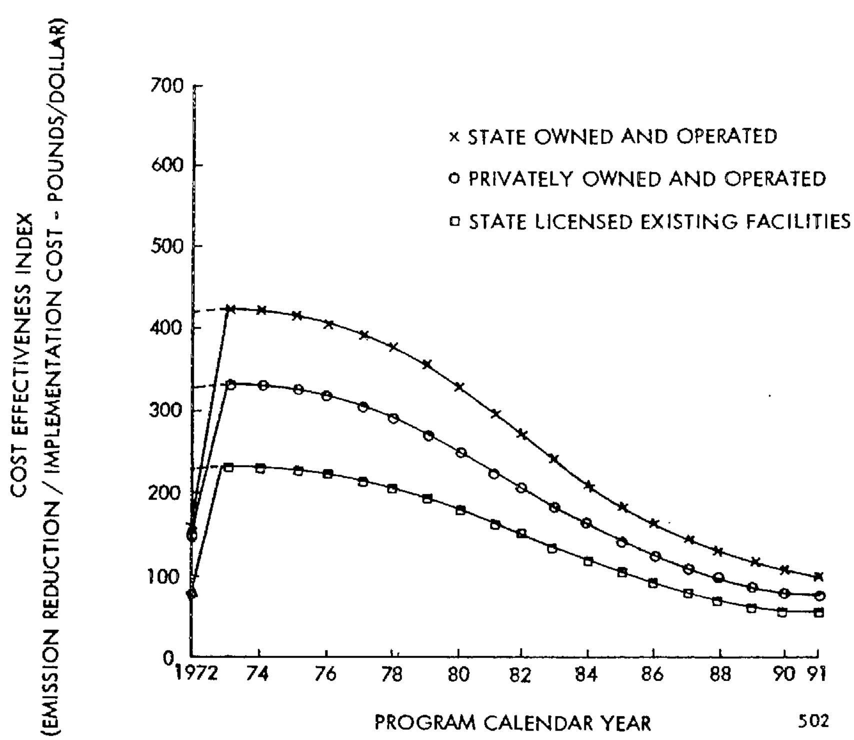

Figure 8-5. IDLE TEST OWNERSHIP AND OPERATION COMPARISON

State-licensed facilities owned by private industry are the least cost-effective on a total program basis because of efficiency factors. More facilities are required to provide population coverage. This is due to the fact that equipment and facilities assigned to the vehicle inspection function are underutilized, similar to current Certificate of Compliance facilities. Additionally, the purchase price of equipment and new facilities, if required, would be higher for the individual who does not enjoy the benefits and economies of large-scale buying.

Figure 8-6 shows the CE of Key Mode test facilities as a function of ownership and operation. Similar to Idle test, the State owned facilities rank ahead of the private industry facilities.

The dotted lines on both Figures 8-5 and 8-6 indicate the relative CE achieved during 1972-1973 if the investment costs were prorated over the total program life. The curve remains essentially the same; however, depending on the time period used (prorated 5, 10, 15, or 20 years), the general curve would be depressed or lowered slightly over that period chosen.

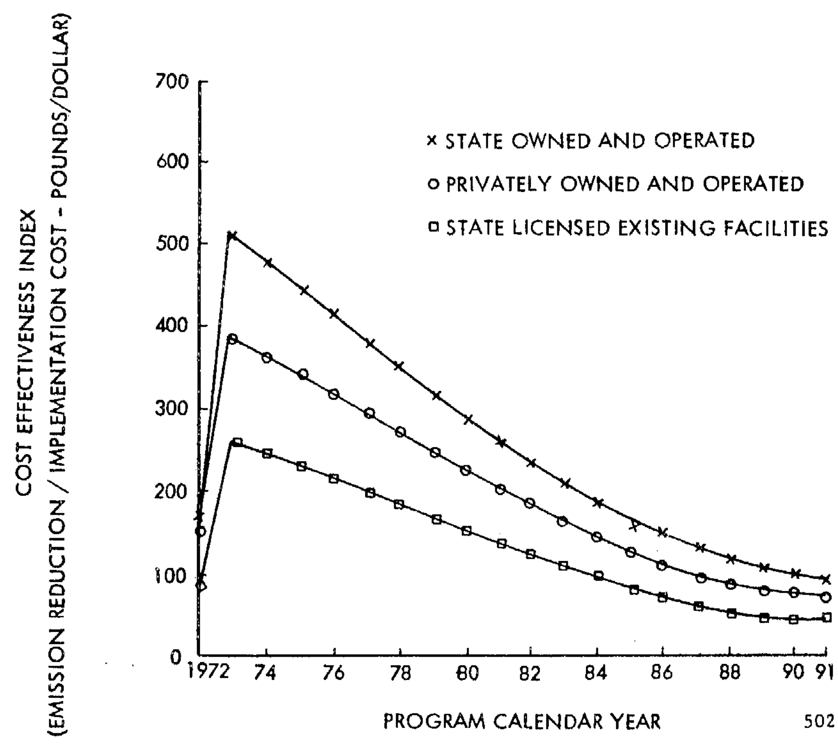

Figure 8-6. KEY MODE OWNERSHIP AND OPERATION COMPARISON

8.1.3.5 <u>Vehicle Owner's Total Cost</u> - In addition to program implementation costs of facility acquisition, operation, and management, there are the vehicle owner's cost. These costs were discussed in Section 6 and included an analysis of each test regime. Assuming the vehicle population increases continuously at the rate of 3.6 percent annually, as discussed in Section 5, the expected vehicle population per year may be calculated. Additionally, it was assumed for analytical purposes, that the average vehicle owner's cost increases at an annual rate of 5 percent.

Figure 8-7 shows the anticipated total vehicle owner's cost on an annual basis for each test regime. For the comparative analysis, an inspection rejection rate of 25 percent is assumed. To determine the costs for a 50 percent rejection rate, the values of the abscissa are doubled; the curves remain the same.

It should be noted that in actual implementation, the cost projections for the 25 percent inspection rejection rate are probably not exactly equal to one-half those for the 50 percent inspection rejection rate. Interpolating the service costs for these looser requirements would require more data acquisition and analysis. However, one point is certainly evident at present; the relationship between service costs and emission reduction achieved as a function of established limits is not linear.

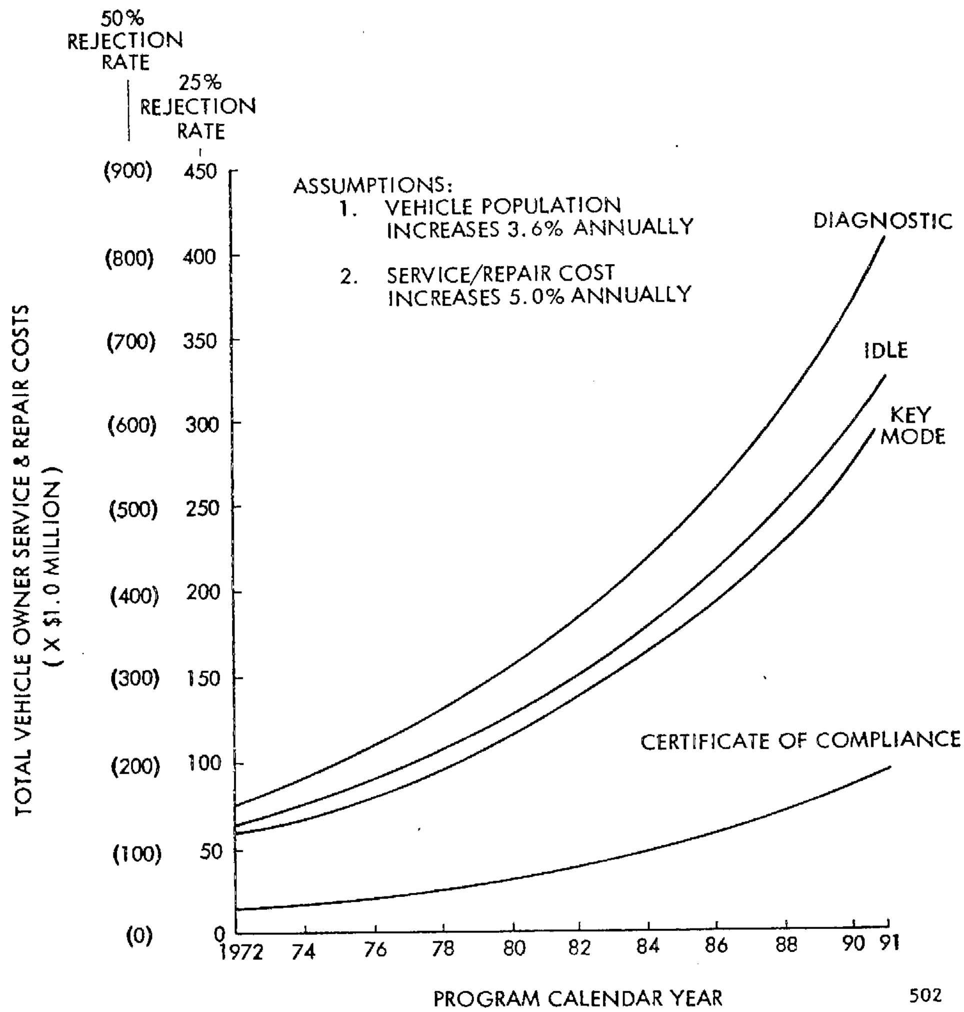

Figure 8-7. ESTIMATED TOTAL VEHICLE OWNER'S SERVICE COSTS BY CALENDAR YEAR

Using the previously discussed results on effectiveness, the revised CE indices, which include the effects of total vehicle owner's service and repair cost, are shown in Figure 8-8. Key Mode exhibits a greater CE index than Idle test from 1972 through 1979. After 1980, the two test regimes are essentially equal. Diagnostic test and Certificate of Compliance remain unchanged relative to Key Mode and Idle test. It is interesting to note that in every case Key Mode remains ahead of Idle

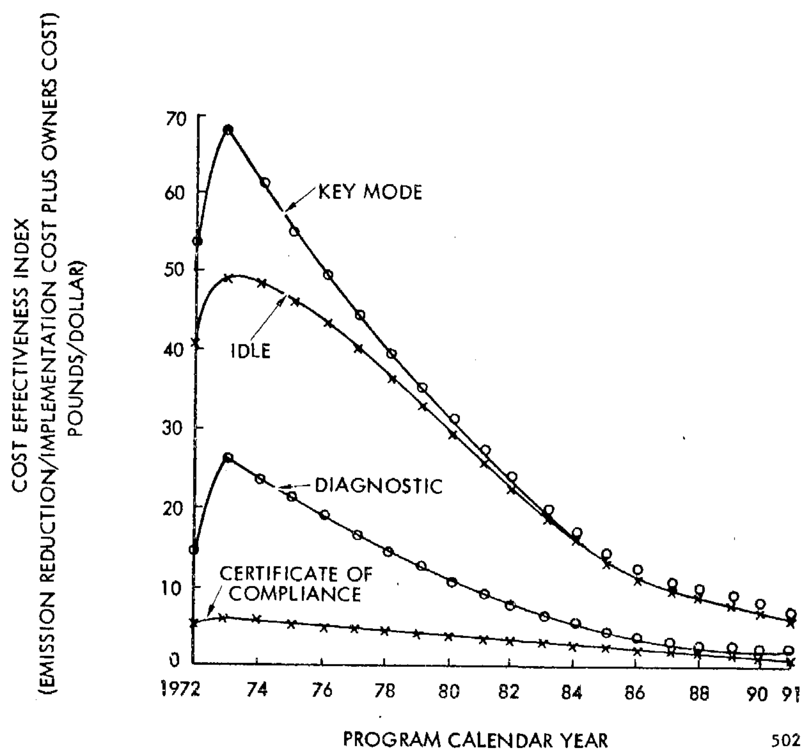

Figure 8-8. COST-EFFECTIVENESS BASED ON IMPLEMENTATION AND VEHICLE OWNER'S COST

up through at least the first 5 years of operation, even when considering the effects of vehicle owner's service and repair costs as part of the program implementation. A detailed analysis of owner's costs as a function of test regimes is presented in paragraph 8.2.

8.2 PUBLIC ACCEPTABILITY CONSIDERATIONS

The cost of maintenance that would be incurred by the vehicle owner for the maintenance performed on 312 vehicles to 1 May 1971 was discussed in paragraph 6.4. The average costs by test regime were:

	All Service	1st Service
Certificate of Compliance (Includes inspection fee)	$ 8.31	$ 7.88
Idle	37.02	27.19
Key Mode	28.24	24.86
Diagnostic	47.48	33.29

The public opinion poll results of Section 7 indicated that the majority of those polled would oppose a mandatory vehicle emission inspection if required repair costs exceeded $10. At this point, it appears that only Certificate of Compliance would be acceptable to the general public.

The following paragraphs will show that the actual annual cost to the vehicle owner for all test regimes is within or close to the public acceptability limit. Three approaches are taken:

- Show the benefits derived through decreased fuel consumption as a result of maintenance
- Show the relation between required repairs and normal repairs made by the average car owner
- Show the benefits of increased vehicle performance.

In addition, the reduction in vehicle emissions due to maintenance performed is demonstrated.

8.2.1 Fuel Economy Benefits

The benefits of fuel economy are important factors in the CE analysis. Clayton Manufacturing Company has run extensive laboratory tests, under controlled conditions with measured air and fuel into the engine, as well as exhaust analyses (reference 30). Typical malfunctions of various types were induced to determine if an increase in exhaust HC and/or CO could be related to an increase in engine fuel demanded to maintain a constant power output. This work, which was verified on a modest number of in-service vehicles, indicated that there is a usable relationship.

Each vehicle and engine has its own basic characteristic of fuel consumption versus work accomplished; therefore, any effort to relate "emission levels" to "miles per gallon" would obviously be very illusive. However, in the June 4, 1968 Federal Register, Vol. 33, HEW included an equation for converting seven-mode HC and CO concentration values to a mass value in grams/mile. Using this equation, a reduction in seven-mode HC or CO concentration (due to repair) can be directly related to the expected pounds (#) of exhaust HC or CO reduction per 1,000, 10,000, or any other desired mileage.

A rise in HC or CO in the exhaust, due to malfunction, represents a loss of potential fuel energy (BTU) that is normally converted in the engine. Therefore, it was reasoned that the engine might demand an equivalent or proportional fuel increase to compensate for the wasted fuel. Additionally, it was concluded that even if a power-robbing engine malfunction existed, the power demanded to drive the seven-mode or any other driving cycle would remain constant.

Ignition misfire, which is the most common cause of gross HC rise, allows fuel to escape without being subjected to combustion. Therefore, the rise in exhaust HC is mainly raw fuel. The same is true for compression loss through burned or sticking exhaust valves. Studies conducted by Clayton indicated that the rise in #/hr of HC in the exhaust does relate directly to the #/hr increase in fuel demanded by the engine at a constant power when using raw fuel BTU/# for the exhaust HC. They also surmised that oxygen also is escaping with the fuel; thus, the estimate would be conservative due to a moderate percentage of HC being burned in the exhaust system at the richer mixtures.

The Clayton study further stated that when exhaust CO increases, this represents a loss of potential fuel BTU being utilized in the engine. That is, when a CO-causing malfunction exists, each pound of increase in CO represents a fuel waste of 4360 BTU by not converting to CO_2. Free hydrogen (H_2) also increases in proportion to CO and represents lost combustion. Their tests showed that engine fuel demand increased at a ratio of approximately 1# of fuel to 3.33# of exhaust CO.

The study stressed that these values cannot be used in relation to gasoline mileage of vehicle (miles per gallon) unless the potential miles per gallon of the vehicle was known. When malfunctions causing an abnormal rise in exhaust HC or CO exist, this increase bears a relationship to the increase in fuel demanded by the engine at constant power output. Relationships found were:

1# FID* indicated HC = 1# increase in fuel demand
1# NDIR** indicated HC x 1.8 = 1# increase in fuel demand
1# NDIR indicated CO = 0.3# increase in fuel demand.

The relationships were verified by inducing a series of malfunctions on seven-mode tests and determining the increase in fuel consumption versus the HEW equation for determining grams per mile. Indications were that the above values are on the conservative side, and that a 1# increase in indicated exhaust HC may demand as high as a 1.2# increase in fuel on some vehicles, depending on engine exhaust configuration.

The above study contained the only available and reasonable method to calculate fuel economy. As such, it will be used below to determine fuel and dollar savings for each test regime. Since the method is applied to each regime, any inherent inaccuracies would apply to all. The intent is to indicate the relative differences.

The equation for arriving at dollar saving per year is derived below:

$$C_s = W \cdot M \cdot K \cdot C_g$$

where

C_s = fuel savings in dollars per year

W = pounds of fuel per mile

M = miles driven per year = 10,000 miles (estimate)

K = gallons per pound fuel constant = $\frac{1}{6.26}$ at specific gravity of 0.75

C_g = cost of gasoline per gallon = \$0.37 (estimate)

1 gram = 2.205×10^{-3} pounds

$$\therefore C_s = 2.205 \times 10^{-3}\, \Delta E \times 10^4 \times \frac{1}{6.26} \times 0.37 \doteq 1.3\, \Delta E$$

where

ΔE = emission reduction in grams per mile.

*FID - Flame ionization device
**NDIR - Nondispersive infrared

The value of ΔE may be found by taking the HC and CO reductions observed and applying them to the following equation:

$$\Delta E = \Delta HC + 0.3\ \Delta CO$$

where ΔHC and ΔCO are in grams per mile.

Applying the above calculations to each of the regimes yields the results shown in Table 8-1. It should be noted that these calculations apply only to those cars serviced, using before and after emission results for each regime. If the fleet is not statistically valid across each regime, the values shown may be misleading. These fuel economy values are calculated from average HC and CO reductions for all vehicles serviced.

Table 8-1. AVERAGE ANNUAL FUEL SAVINGS BASED UPON EMISSION REDUCTIONS

Test Regime	ΔHC (Gr/Mi)		ΔCO (Gr/Mi)		Annual* Fuel Savings ($)	
	All Service	1st Service	All Service	1st Service	All Service	1st Service
Certificate of Compliance (125)**	0.74	0.35	0.66	0.48	1.22	0.64
Idle Test (55)**	2.35	2.04	28.33	22.87	14.10	11.57
Key Mode Test (64)**	2.41	2.12	40.00	37.53	18.73	17.39
Diagnostic Test (68)**	3.00	2.36	23.92	16.46	13.23	9.49

*Based upon 10,000 miles per year
**Number of vehicles in this test group

8.2.2 Average Annual Cost of Repairs

The typical motorist has his car tuned up on the average of once every 18 months. One extensive survey (reference 31) indicated that the average expense for this tuneup was $7.81 on an annual basis. Because of the age of this survey, it is felt that a more realistic present value (at 5 percent a year for 10 years) would be $12.72. It must be stressed that this is an average of all tuneups, from a simple adjustment at a few dollars to a major tuneup of up to $75.00.

A general tuneup consisting of engine diagnosis, new spark plugs, distributor points, condenser, dwell and timing adjustment, adjustment of carburetor idle speed and mixture, and cleaning and testing the function of the smog control valve for an 8-cylinder engine would cost an average of $25.00 (reference 32). If this were done voluntarily, when performance degraded to an unacceptable level (at approximately 18 months), the average annual cost would be $16.67.

It therefore appears that the estimated average annual cost that a motorist would normally expend is somewhere between $12.72 and $16.67. For this discussion, $15.00 will be used; a figure felt to be conservative.

8.2.3 Survey of Vehicle Owner Comments After Service

An important aspect of mandatory vehicle inspection is whether the vehicle performance has changed (better or worse) after maintenance when a vehicle fails the emission test and requires service. An integral part of the 1200-vehicle test program (Part B of this study) is to ascertain from owner comments whether there has been a change in performance as determined by the vehicle owner. To determine these changes, a post card questionnaire was developed and was given to each vehicle owner after his vehicle was serviced. Figure 8-9 is a copy of the prepaid reply post card.

Your car was tested for exhaust emissions and serviced by garages. Please indicate below your opinion of how the car's engine is now performing. Comments are encouraged. Return prepaid reply as soon as possible.

Thank You

☐ No Change ☐ Improved ☐ Worse

COMMENT: ______________________

Figure 8-9. SERVICED VEHICLE PERFORMANCE QUESTIONNAIRE

The reply card provided the owner with three options: no change, improved, or worse. In addition, space for comments was provided, which allowed the owner to describe or state any descriptive information he may wish to express.

Responses were tabulated as a function of these characteristics to determine whether a particular test regime or type of vehicle was sensitive to the type of repair performed. A summary chart, Table 8-2, shows the results in percent. As is seen in the results, the Idle test, Key-Mode test and Diagnostic test are very close to each other as far as percentage improved, no change, or worse opinions. The Certificate of Compliance had a lower percentage of improvement with respect to the other regimes, with an increased percentage of no change and worse. This follows from both the emission results and the test procedures used, because very little maintenance was performed on the vehicles. This is reflected in the owner repair

Table 8-2. SUMMARY OF VEHICLE OWNER COMMENTS

Test Regime	Performance			Responses (to 4/26/71)	Cars Serviced (to 4/26/71)
	No Change (%)	Improved (%)	Worse (%)		
Certificate of Compliance	37.5	45.5	17	64	112
Idle Test	28	59.5	12.5	32	51
Key-Mode Test	21	68.5	10.5	38	54
Diagnostic Test	28	61	11	36	62
Total	30	56.5	13.5	170	279

cost results. In addition, on vehicles which had faulty emission control systems, when these systems were restored, an obvious change in performance was encountered.

8.2.3.1 Results - At the time of tabulation for this report, 279 vehicles received service as a result of not meeting the established emission limits. Each vehicle owner was given a return reply card when the vehicle was returned to the participant. To 26 April 1971, 170 of the 279 participants returned the reply cards. Table 8-3 shows the responses as a function of the test regime, vehicle type (controlled or uncontrolled), and opinion of engine performance.

Table 8-3. VEHICLE OWNER COMMENTS AFTER SERVICE

Test Regime	Performance			Responses (to 4/26/71)	Cars Serviced (to 4/26/71)
	No Change	Improved	Worse		
Certificate of Compliance					
Uncontrolled	11	18	5	34	59
Controlled	13	11	6	30	53
Idle Test					
Uncontrolled	7	9	1	17	28
Controlled	2	10	3	15	23
Key-Mode					
Uncontrolled	6	15	3	24	35
Controlled	2	11	1	14	19

Table 8-3. VEHICLE OWNER COMMENTS AFTER SERVICE (Continued)

Test Regime	Performance			Responses (to 4/26/71)	Cars Serviced (to 4/26/71)
	No Change	Improved	Worse		
Diagnostic					
Uncontrolled	5	13	3	21	44
Controlled	5	9	1	15	18
Total					
Uncontrolled	29	55	12	96	166
Controlled	22	41	11	74	113
Grand Total (All)	51	96	23	170	279

It is interesting to note that approximately 90 percent of the worse-reply opinions were related to the carburetor operation problems. These common complaints were: hard cold-starting, engine stalls at stops, and rough idles. These symptoms are results of improper choke adjustment and improper speed and/or mixture adjustments. The remaining complaints covered improper timing adjustments, and car "shakes" and "shimmies," etc.

In summary, of those responses received, when a service was performed, a total of 13.5 percent experienced, in their opinion, a degradation in engine performance. A total of 30 percent felt there was no change. Excluding Certificate of Compliance vehicles, it may be concluded that these drivers were operating vehicles which were emitting excessive CO and HC pollutants and, when serviced for lower emissions, did not notice any performance degradation. Finally, the majority of the vehicle owners (56.5 percent) felt their vehicle was definitely improved in performance and resulted in a significant benefit.

8.2.4 Vehicle Emission Reduction

As a result of the maintenance performed, an average reduction in emissions was observed in almost all test regimes for HC and CO. NO_x increased roughly as an inverse function of CO. Table 8-4 shows the reductions by test regime.

8.2.5 Cost Effectiveness for the Vehicle Owner

Unfortunately, the average motorist is more concerned with the costs with which he may be faced as a result of mandatory inspection than he is with reducing air pollution. As an example, although 30.2 percent of the public opinion group thought the major benefit of a mandatory inspection was to reduce air pollution, $10 worth of repairs would be acceptable to 46.1 percent and $20 worth of repairs would be acceptable to 22.6 percent. The conclusion, then, is that 13.9 percent of the group would make repairs of $10, and only 6.8% of the group would make repairs of $20 <u>because it would reduce air pollution</u>. Even if <u>every one</u> of the persons willing to spend $20 thought they would reduce air pollution, 7.6 percent dropped out because of cost.

Table 8-4. AVERAGE EMISSION REDUCTION FOR SERVICED VEHICLES BY TEST REGIME

Vehicle	HC (Gr/Mi)		CO (Gr/Mi)		NO_x (Gr/Mi)	
	After All Service	After 1st Service	After All Service	After 1st Service	After All Service	After 1st Service
Controlled						
Certificate of Compliance	0.93	0.93	0.82	0.82	(-0.17)	(-0.17)
Idle	1.44	1.27	30.35	22.40	(-0.60)	(-0.39)
Key Mode	2.23	2.13	32.07	27.86	(-0.68)	(-0.44)
Diagnostic	0.41	0.36	14.49	11.80	(-0.33)	0.03
Uncontrolled						
Certificate of Compliance	0.56	(-0.21)	0.50	0.16	(-0.23)	(-0.19)
Idle	3.06	2.63	26.77	23.23	(-0.23)	(-0.30)
Key Mode	2.50	2.11	44.16	34.38	(-1.11)	(-0.85)
Diagnostic	4.01	3.13	27.58	18.27	(-0.62)	(-0.47)
All Vehicles						
Certificate of Compliance	0.74	0.35	0.66	0.48	(-0.20)	(-0.18)
Idle	2.35	2.04	28.33	22.87	(-0.39)	(-0.34)
Key Mode	2.41	2.12	40.00	37.53	(-0.96)	(-0.71)
Diagnostic	3.00	2.36	23.92	16.46	(-0.54)	(-0.33)
NOTE: Negative value indicates increase						

The results of the previous paragraphs are combined into one table (Table 8-5). The fuel savings described in paragraph 8.2.1 were based on the pollutant reductions at the time of service. To present a more pessimistic view, degradation in fuel economy is assumed here to be linear for a 50 percent reduction in the figures given. This degradation is taken into account in Table 8-5.

To obtain a net cost to a motorist whose car fails the emission test, the average cost for service was obtained. With the exception of Certificate of Compliance, the service performed represents at least a minor tuneup, including replacement of common ignition parts. Accomplishment of this mandatory service obviates the need for the average annual outlay for a tuneup, so the additional cost of maintenance is the cost for mandatory service minus $15.00. The emission reduction virtually

Table 8-5. VEHICLE OWNER'S COST-EFFECTIVENESS SUMMARY FOR SERVICED VEHICLES

Cost and Effectiveness Elements	Certificate of Compliance (125)	Idle (55)	Key Mode (64)	Diagnostic (68)
Service Cost ($)				
All Service	8.31	37.02	28.24	47.48
1st Service	7.88	27.19	24.86	33.29
Estimated Annual Cost of Tuneup, Obviated ($)	-	15.00	15.00	15.00
Fuel Savings ($)				
All Service	0.66	7.05	9.37	6.67
1st Service	0.32	5.79	8.70	4.75
Net Cost ($)				
All Service	7.65	14.89	3.87	25.80
1st Service	7.56	6.40	1.16	13.54
Reduction in Emissions (HC + CO) (Gr/Mi)				
All Service	1.40	30.68	42.41	26.92
1st Service	0.83	24.91	39.65	18.82
Cost per Gram Reduction ($)				
From Service Cost				
All Service	5.94	1.21	0.67	1.76
1st Service	9.49	1.09	0.63	1.77
From Net Cost				
All Service	5.46	0.49	0.09	0.96
1st Service	9.11	0.26	0.03	0.72
Performance Assessment by Vehicle Owner (%)				
Improved	45.5	59.5	68.5	61.0
No Change	37.5	28.0	21.0	28.0
Total	83.0	87.5	89.5	89.0

guaranteed by the proper tuneup procedure, enforced by the possibility of retesting the vehicle after service, will result in a fuel saving that can be used to reduce the net cost to the motorist. While it is true that a tuneup not required because of failing the emission test may also result in a fuel savings, it is a hit-or-miss proposition.

The net cost to the owner of a failed vehicle is therefore within the $10.00 acceptable cost with the exception of Diagnostic, which has an average cost of $13.54 after one service. Certificate of Compliance and Key Mode costs are still acceptable after all service. Idle goes to almost $15.00, while Diagnostic moves far beyond the acceptability limit.

The emission reduction summary shows that Certificate of Compliance provides insignificant reductions, while Key Mode shows more of a reduction after first service than any other test after all service, and the least dollar cost per gram reduction.

Therefore, from the vehicle owner maintenance cost standpoint, based on net cost or emission reduction, Key Mode is the most acceptable test for implementation.

8.3 CONSIDERATION OF UNCERTAINTY FACTORS

The preceding analysis considered the quantitative factors of emission reduction and program cost for each of the four test regimes. Based on operational data and other available information, estimations and projections were made for the next 20 years, beginning in 1972. Wherever possible, relevant data were quantified and used.

There are other factors to be considered in determining which of the four alternatives would be the most suitable to implement. These factors have been classified as uncertainty factors because they consider characteristics relevant to the program and which are dependent on future circumstances. For example, the effects of future regulations and technological advancements cannot be quantified; consequently, their impact on each of the test regimes can be evaluated and compared only on a qualitative basis. In the following paragraphs, these factors are discussed and evaluated on a qualitative basis wherever possible.

8.3.1 Effects of Future State and Federal Regulations

Section 2 discussed the trends in both State and Federal regulations regarding vehicle emission limits. As the tighter limits are imposed, more extensive instrumentation and better measurement resolution and accuracy would be required. It is also evident that mass emissions (equivalent weight per mile) will remain as the accepted measurement standard.

These tighter emission standards will have considerable effect on instrumentation requirements by 1975. The constant volume sampling (CVS) emission measurement technique becomes a requirement in 1972. The CVS procedure requires dynamic loading of the vehicle, normally accomplished by a dynamometer. Consequently, both Certificate of Compliance and Idle test would not be applicable to this type of emission inspection.

The Key Mode and Diagnostic test regimes both utilize dynamometers, with the former requiring a simpler and cheaper one than that required for Diagnostic or CVS testing. The basic Key Mode dynamomemter would require the addition of the capability to adjust loads and inertial weight. Facility requirements would not change significantly for either regime due to CVS requirements; however, the sampling and instrumentation package, as described in Section 3, would require an additional $20 to $25,000.

The application and degree of end-of-assembly line (EOAL) testing, as directed by future State or Federal regulations, would directly affect a periodic vehicle inspection program. Assuming that EOAL testing is totally effective in identifying subnormal performance, then grossly malfunctioning components would be corrected at the point of assembly or immediately thereafter. Minor adjustments also would be performed prior to resorting to remove-and-replace activities. It seems conceivable that subsequent inspections on a statewide level would detect adjustments that deviated and/or component deterioration due to wear. The requirements for this type of inspection program would be more of an enforcement of regulations, presently being considered, that would require manufacturers to guarantee a specified emission level over an initial period of the vehicle's expected life.

8.3.2 Anticipated Future Emission Control Methods

Controlling vehicle emissions on future vehicles will be primarily by catalytic or thermal exhaust conversion plus engine modifications. The engine modifications will probably include fuel injection, atomizing carburetion, exhaust recycling, programmed spark advance, prolonged cylinder dwell time, and hybrid (internal combustion plus electric) engines. Additionally, the Wankel rotary engine is currently being introduced and marketed, and shows some promise as a low emitter.

Fuel modifications also would affect pollutants emitted in future vehicles. Based on very limited foreknowledge, it seems that many of the modifications and devices would be intentionally nonoperative during part of a driving cycle. Consequently, it would be necessary to simulate a driving cycle or road conditions to achieve reasonable engine rpm or torque (horsepower) to measure actual emission characteristics.

As an example, some catalytic afterburners are nonoperative at high-temperature conditions to conserve on the catalytic media. Other devices incorporate thermostatic overrides to functionally protect either the engine or the device from failure during above-normal engine operating temperatures. These devices would necessitate engine loading capability to adequately evaluate emission control performance.

8.3.3 Estimation and Projection of Emissions Reduction

The effectiveness calculations were made for two periods of vehicles: 1957-1970 and 1971-1991. Projections for the 1971-1991 model-year vehicles were based on average reductions measured for the 1968 through 1970 vehicles. Although the method was applied equally to each test regime, it must be recognized that the sample size for each regime and for each model-year vehicle was limited.

At this stage of the testing phase, which is approximately half completed, there is no assurance that the emission reductions noted in the first half for the 1968-1970 vehicles will be duplicated in the second half. Presumably, the changes, if any, would be small. However, since the calculations for the 1971-1991 vehicles were based on these vehicles and would constitute the majority of the population for the program duration, small inaccuracies between test regimes may become significant when multiplied by the several million vehicles considered.

In view of these uncertainties, the effectiveness projections were presented in two formats. One format considered only 1957-1970 vehicles for which emission reductions were measured and calculated. The other format included the 1971-1991 vehicle emission reduction estimates with the measured reductions for the 1957-1970. Doing this, the influence of the estimated projections could be determined. The results of the effectiveness figures indicate that these projections did not alter the ranking of alternatives.

8.3.4 Estimation and Projection of Program Costs

All cost inputs obtained were the best figures available, and all total costs were calculated using the computerized cost model. However, some degree of uncertainity exists in the final figures computed, such that the eventual cost of implementing the various configurations of each of the regimes costed may vary to some extent due to varying cost increases with time or conditions in the marketplace.

To account for these uncertainties, a parametric analysis was performed for all variables whose values were determined to be critical in the cost analysis. Land and building costs, equipment costs, and personnel wages and salaries were varied ±20 percent to determine their net effect on total program investment and operating costs. The higher cost figure considered might be more accurate for investment and operating costs as the period of time between study completion and actual program commencement widens. Actual cost variations that may be experienced are particularly crucial in the area of land acquisition, facility construction, and personnel salaries. If these costs do in fact vary by as much as the allotted parametric range, the maximum quoted aggregate costs would be experienced. Aggregate land and construction costs are particularly sensitive when cost estimates are based upon a unit cost per square foot. It is for this reason that a 20 percent variability was considered. If as long as 3 years elapse prior to implementation, operating costs as a function of time alone may increase by 15 percent due to price escalations. Again, 20 percent was allotted as the maximum variability anticipated.

8.3.5 Private Enterprise Program Participation

In determining the program implementation costs, it was assumed that private industry would participate in varying degrees, depending on type of management, ownership, and operation considered. For the Certificate of Compliance test regime, privately owned and operated service facilities are currently licensed. A larger quantity of new or existing facilities would be required to implement a vehicle emission inspection program. Each existing facility owner would be required to invest in specialized emission test equipment costing up to $2,000. New facilities would require $3,600 in original equipment. Based on the analysis of results obtained during this study, facilities would be under more stringent surveillance than presently imposed to assure desired performance and program effectiveness. Approximately 1366 lanes would be required.

Idle test regime facilities owners would require investments in site, facilities, and special Idle inspection test equipment. There would be a smaller quantity of lanes required than for Certificate of Compliance due to the shorter inspection time, thus faster throughput rate. New facilities would cost about $20,000 and would require $10,000 for special equipment. Approximately 319 lanes would be required.

Key-Mode test regime requires more extensive instrumentation than the Certificate of Compliance or Idle test regimes. Typical new facilities for the private owner and operator would cost $40,000 and would require equipment costs of $13.000. Approximately 398 lanes would be required.

The Diagnostic test facility would require an acquisition investment of $135,000 for the facility and $32,000 for the inspection equipment. Due to the very low throughput rate, approximately 784 lanes would be required.

The public opinion survey, previously discussed in Section 7, indicated that vehicle owners are leery of private garages and service stations, especially in terms of corrective maintenance and repairs. Thus, if privately owned inspection facilities are incorporated, it would be almost mandatory for the State to assure that a facility performing inspection does not also perform the recommended service and repairs. This may be very difficult to enforce. Possibilities for collusion and graft exist.

Service facilities profits are realized to a greater extent on products sold, rather than on labor charges. It becomes difficult to visualize then, that many facility owners would be interested in investing thousands of dollars just to provide emission inspection services. Financial disadvantages are least severe beginning with Certificate of Compliance and become increasingly worse with Idle and Key Mode, ending with the worst of all, Diagnostic.

It could be argued that a mandatory periodic inspection program provides a captive clientele. This may be true to a certain extent. However, there is no guarantee that all participants in a given area will patronize a designated facility. For a given implementation, it is assumed that the State would establish basic inspection fees based on anticipated workload, operating costs, and acceptable profit margin. When variations occur in vehicle throughput and/or operating costs, profit margin is affected. This may be very oversimplified. The above discussions are a few of the considerations that would determine whether or not necessary private industry participation can be realized to fulfill program implementation requirements for privately owned and operated inspection facilities.

8.3.6 Program Objective - Immediage and Long-Range

The overall program objective is to achieve emission reduction in terms of HC, CO, and NO_x. Measures of effectiveness were calculated based on this objective. The selection between the alternatives will be facilitated by the quantitative CE indices developed as a function of calendar years. What remains is to evaluate these quantitative measures against the program goals.

To start with, is the intent of the program to achieve the greatest reduction of vehicle emissions during the first year or during the first 5 years? If it is during the first 5 years, then State owned and operated Key Mode facilities is the most desirable alternative. If the program intent is to achieve the greatest reduction for the least investment cost incurred during the first year of operation, then State owned and operated Idle test facilities would be the recommended approach.

If the program goal is to realize the greatest emission reduction during the next 5 years (beginning in 1972) for the least costs expended, then State owned and operated Key Mode facilities would be the selection. Considering total investment costs plus 5 years of operation, Key Mode would be at least 10 percent more cost-effective than Idle. Total expenditures would be $73.7 million for Key Mode and $62.2 million for Idle. Emission reductions would be 13.1 million tons for Key Mode and 10.8 million tons for Idle test.

Is the program goal to achieve the most cost-effective solution during the next 20 years by incorporating a statewide inspection program? If this is the objective, then either Key Mode or Idle test facilities owned and operated by the State should be implemented.

If the intent is to achieve the greatest reduction with the least cost to the vehicle owner in terms of service and repair expense, then Key Mode would be the selection. In paragraph 8.2, it was shown that Key Mode realizes the greatest average emission reduction for the least vehicle owner's cost.

In its entirety, paragraph 8.3 has attempted to raise questions and identify areas of concern that would affect the ranking and selection of the alternatives. The intent is not to invalidate the analyses, but merely to identify areas that are dependent on future circumstances but which affect current decisions.

8.4 EVALUATION OF THE COST-EFFECTIVENESS ANALYSIS

The cost-effectiveness analysis of the test regimes has shown that State management, ownership, and operation of inspection facilities is the most desirable. Regardless of test regime type considered, a State regulated program featuring private industry management, ownership, and operation of inspection facilities was ranked next in order. The least cost-effective approach was State management of existing, licensed inspection facilities owned and operated by private industry.

The relative cost-effectiveness ranking of four alternative test regimes evaluated was as follows: Key-Mode test, Idle test, Diagnostic test, and Certificate of Compliance. Evaluated on a total program basis, Key-Mode was ranked first for every arrangement of program management and inspection facility ownership and operation. Idle test was essentially equal to Key-Mode after the initial 5 to 7 years of operation. The following paragraphs summarize the cost-effectiveness analytical results.

8.4.1 Key-Mode Test

The Key-Mode test regime exhibited the greatest emission reduction for the resources and funds expended when compared with three other alternative test regimes. It is a highly developed and refined procedure first introduced by the Clayton Manufacturing Company. The inspected vehicle is driven under simulated road conditions. Using three modes of operation (idle, low cruise, and high cruise), the vehicle is then monitored and exhaust gases sampled. An integral part of the inspection test procedures is a set of tables that relate excess emission levels of HC and CO to specific areas of vehicle service and repair. Reference to supplementary charts enables maintenance personnel to perform rapid and accurate service and repair. Short inspection time (average 6 minutes per vehicle), coupled with explicitly defined areas of service and repair, results in lowering emissions to desired levels while keeping costs to a minimum.

The fast throughput rates per inspection facility result in efficient and economical station operation and lower total program costs. It was shown that Key-Mode test realized the greatest emission reduction per vehicle owner's cost. Considering the potential fuel savings per serviced vehicle, Key-Mode test is the most cost-effective in terms of emission reductions per vehicle owner's costs and benefits. A survey of those vehicles serviced by the Key-Mode procedure revealed that 68.5 percent of owners considered the post-service performance to have improved while 20 percent believed no change or degradation in performance occurred.

8.4.2 Idle Test

The Idle test regime was the second most cost-effective method. In fact, depending on the emission weighting factors considered, it even exceeded Key-Mode in terms of cost-effectiveness after the initial 7 years of program duration. The total program effectiveness data (emission reduction achieved) showed that Idle test was slightly less effective than Key-Mode. Correspondingly, the cost analysis showed that Idle test was slightly less costly than Key-Mode.

The advantages of an Idle test and inspection program are that the technicians conducting the tests are equipped with established procedures and equipments to properly service a vehicle with the intention of reducing emissions and without sacrificing vehicle performance. Technicians trained in the proper use of the Idle equipments can perform rapid emission measurements, interpret the results, and diagnose causes of excessive emissions. Both the equipment and the procedures are easy to use.

The Idle test regime inspection does not require extensive testing of the vehicle to determine various operating levels of emissions as does the Key-Mode. Consequently, the failure detection methods of isolating cause of excess emission is also less extensive. These characteristics are reflected in the effectiveness measures and vehicle owner's cost data which revealed that Idle test achieved less emission reduction per vehicle owner's cost than did Key-Mode.

8.4.3 Diagnostic Test

The Diagnostic test depends on the training, experience, and technical judgment of a skilled diagnostician to evaluate engine performance and to determine causes for excess emission levels. To assist him, the diagnostician has various instrumentation and documentation available to identify and classify malfunction symptoms along with service and repair actions required.

Results of efforts to reduce emissions on the test vehicles tend to indicate that relying on the technical personnel staff to identify causes for excessive emission levels was not effective. Theoretically, a Diagnostic test should be as effective as Key-Mode, because both rely on simulated road-load conditions of the tested vehicle using a dynamometer to identify malfunctions and maladjustments.

Failure diagnosis for the Key-Mode is facilitated through the truth charts which were developed by skilled diagnosticians interpreting operational test data. Diagnostic test relies on the charts accompanying the separate instrumentation equipment, and to a large extent, on the training, education, and experience of the technical staff. It is not as regimented as Key-Mode diagnostics, which may or may not be an advantage. Although there are some benefits to flexibility, Diagnostic test effectiveness results indicated that the formal methods of Key-Mode are more desirable.

In terms of cost-effectiveness, the Diagnostic test regime was less beneficial than Key-Mode and Idle due to its relatively low vehicle throughput and extensive instrumentation. More and larger facilities were required to accommodate the inspected vehicles, and expenditures were much higher for annual operating costs. Combining the relatively low effectiveness with high operating and investment costs, the Diagnostic test regime was ranked below Key-Mode and Idle.

8.4.4 Certificate of Compliance

The Certificate of Compliance was relatively ineffective in achieving emission reductions. This is understandable since this test regime does not specify acceptable levels of HC, CO, and NO_X. Certification requirements, if satisfied, assured that exhaust control devices and emission control systems were operating according to manufacturer's specifications. Additionally, an implicit requirement was that the engine also was operating according to manufacturer's specifications. However, as determined from post-service seven-mode tests, engine operation did not meet these specifications in all cases.

The cost-effectiveness analyses indicated that Certificate of Compliance was the least desirable of the regimes evaluated, even if the service cost is considered as part of the anticipated inspection fee. It realized a relatively low effectiveness measure and comparatively high annual operating costs on a total program.

SECTION 9
STATE VERSUS PRIVATELY OPERATED STATIONS
COST-EFFECTIVENESS ANALYSIS

This section determines the extent to which the State of California and private industry should participate in a statewide program of mandatory vehicle emission inspection. It has been shown that it is technically feasible for an inspection program, coupled with directed corrective maintenance and adjustments, to result in reduced emission levels. Both the cost analysis and the cost-effectiveness analysis have indicated the reasonableness of having both State and private industry participate in the total program.

The questions of who should manage the total program, who should own the inspection facilities, and who should operate and maintain the facilities have been addressed or alluded to in various sections of this report. Functional requirements were discussed in Sections 2 and 4, where it was essential to identify total program management functions and also inspection facility ownership and operation functions. Based on these requirements, various facilities were configured, along with possible program management structures. These different combinations were then priced and used as inputs to the cost analysis discussed in Section 6, whereas the cost-effectiveness of these combinations were evaluated in Section 8.

The purpose of this section is to collect the distributed analyses and summarize the findings to clearly identify and describe the roles of the State and private industry. This section begins with a brief functional description of program management, and inspection facility ownership and operation. Following this, a qualitative cost analysis of State and private industry participation is performed based on the functional allocation. The quantitative cost analysis of the different arrangements as used in the cost-effectiveness discussions are evaluated. The results of the public opinion survey are considered prior to determining the degree of participation that the State and the private sector would have in a statewide inspection program.

9.1 PROGRAM ADMINISTRATION AND MANAGEMENT

Total program management of the statewide inspection system will include the scheduling of vehicles, maintenance of records, establishing and reviewing of emission limits, evaluating current and future instrumentation requirements, and providing for future analysis and development in the areas of methodology and technology. The administration and surveillance of statewide inspection facilities will involve the establishment of qualification criteria for equipment and facilities, evaluation of candidates, and the certification and acceptance of selected units. These functions will be performed during the program lifetime.

At the outset of the program, the management agency will conduct, or will cause to be conducted, the necessary indoctrination, orientation, and training sessions for the general public and the pertinent technical personnel. To assure uniform performance of vehicle inspection for a given test regime, the management agency will issue accepted inspection test procedures to all participating facilities, review initial emission inspection results, and upgrade inspection procedures as required.

9.2 INSPECTION FACILITIES OWNERSHIP AND OPERATION

Inspection facility ownership will include those functions of site acquisition, facility construction, equipment acquisition and installation, and personnel selection and training. Where suitable facilities exist, modifications to accommodate a given test regime may be required. Additionally, special equipments may be required to perform emission inspections. Depending on the test regime implemented, training may be provided by program management or on-the-job by facility management. Facility operation and maintenance will involve performing vehicle emission inspection, consulting with the vehicle owner on test results, and recording and managing inspection data and records. Equipment and facility maintenance functions will be performed by in-house personnel or contracted to service agencies. In addition, there will be the normal business administration functions of paying operating expenses such as salaries, taxes, utilities, expendable supplies, and payments on long-range loans or martgages; handling and accounting of inspection fees if required; and other such functions.

9.3 QUALITATIVE COST COMPARISON

Section 6 addressed implementation costs to both the State and private industry. The expenditures that were quantified and calculated are the actual estimated and projected costs incurred for a particular arrangement of total program management and inspection facility ownership and operation. That is, no differentiation was made between cost to the State or private industry. Obviously, for total State involvement including management, ownership, and operation, all costs are financed by the State (excluding the possibility of inspection fees). When the arrangement consists of private ownership and operation of inspection facilities, then direct State finances are necessary only for program surveillance personnel and related costs. The same would apply for State licensing of privately owned and operated facilities.

Table 9-1 contains a qualitative comparison of State and private industry as a function of various cost elements. The program cost implications in terms of State finances are evaluated. It becomes readily apparent that if the concern is cost-effectiveness as related to State expenditures, then State surveillance of a program managed by a private enterprise and comprised of privately owned and operated facilities would be the best selection. Contrarily, should the concern be cost-effectiveness in terms of general economy, then total State participation would be the choice.

9.4 COST-EFFECTIVENESS COMPARISONS

Section 8 evaluated and compared the test regimes based on different arrangements of management, ownership, and operation of inspection facilities. For each test regime, three basic arrangements were considered: (1) State managed, owned, and operated; (2) private industry managed, owned, and operated; and (3) State managed with licensed, existing, privately owned facilties.

Table 9-1. QUALITATIVE COMPARISON OF STATE AND PRIVATE INDUSTRY

Cost Categories and Considerations	State Participation	Private Industry	Total State Program Cost Implication
1.0 <u>Research and Development</u>			
Instrumentation	Requirements analysis, specifications	Design, development, manufacture	Minimal State cost
Advanced Technology	Technical cognizance, basic research	Basic research	Minimal State cost
2.0 <u>Acquisition and Investment</u>	(State owned, operated)	(Private owned, operated)	
Site Acquisition			
Purchased	High initial cost or long-term financing	High initial cost or long-term financing	No cost to State if privately owned
Leased	Annual leasing cost	Annual leasing cost	Moderate cost to State if leased; highest cost to State if purchased
Facility Plans and Bids	Single department cognizance; similar building types, plans	Possibly many separate bids, plans, agencies	No cost to State if privately managed; moderate cost to State if State managed
Facility Construction and Acceptance	Single contracting agency, single inspection/acceptance agency	Possibly many separate contracting agencies State/County/City building inspection approval	No additional cost to State if privately owned facility; moderate cost to State if facility leased; high cost to State if facility owned

Table 9-1. QUALITATIVE COMPARISON OF STATE AND PRIVATE INDUSTRY (Continued)

Cost Categories and Considerations	State Participation	Private Industry	Total State Program Cost Implication
2.0 Acquisition and Investment (Continued)			
Equipment Acquisition and Installation	Single contracting agency and departmental responsibilities	Possibly many separate contracting agencies; requires some guidance from State agency on requirements	No cost to State if privately owned; moderate cost to State if leased; highest cost to State if owned
Initial Personnel Training and Indoctrination	Single department responsibility; uniform training policy, course content; minimum quantity of trained instructors, equipment, buildings	Possibly many diverse training policies, course contents, equipment, facilities, instructors; requires some guidance from State agency on requirements	Minimal cost to State if privately owned; moderate cost to State if State owned
Station Qualification and Certification	Single departmental responsibility; uniform qualification and certification policies; minimum quantity of technical and administrative personnel	Probably mandatory that State qualify and certify the stations	Moderate cost to State
Vehicle Scheduling	Single departmental responsibility	Probably mandatory that State be responsible	Minimal cost to State
3.0 Operation and Maintenance	(State owned operated)	(Private owned, operated)	
Facility Inspection Personnel Salaries, Wages, Benefits	Technical rating dependent on test regime; cost proportional to technical requirements; salaries and benefits must be competitive to attract higher-rated personnel	Technical rating depends on test regime; cost proportional to technical rating	No cost to State if privately owned; highest cost item to State if State operated

Table 9-1. QUALITATIVE COMPARISON OF STATE AND PRIVATE INDUSTRY (Continued)

Cost Categories and Considerations	State Participation	Private Industry	Total State Program Cost Implication
3.0 Operation and Maintenance (Continued)			
Facility Administrative Personnel	Minimal clerical requirements	Minimal clerical requirements	Minimal cost to private and State
Personnel Training and Upgrading	May require additional personnel ratings/grades for technical advancements; minimal sustaining training for new personnel, probably on-the-job training	Possibly diverse methods of upgrading personnel; minimal sustaining training for new personnel, probably on-the-job training	Negligible cost if privately owned; minimal cost if State owned
Maintenance and Support, Inspection-Oriented Equipment	Preventive maintenance done by facility personnel, minor corrective maintenance done by facility personnel, major corrective maintenance done either by a single technical department or contracted outside service	Preventive and minor corrective maintenance done by facility personnel; major corrective maintenance probably done by contracted service	No cost to State if privately owned/operated; major operating cost element if State operated
Maintenance and Support, Support-Oriented Equipment	Periodic confidence testing and calibration functions; minor repairs of supporting equipments done by facility personnel, major repairs done by single department or contracted	Periodic confidence tests and calibration functions; minor repairs of support equipments done by facility personnel, major repairs contracted	Minimal costs to private industry or State
Maintenance and Support, Administrative Equipment	Periodic maintenance and servicing; minor repairs/service by department personnel, major repairs contracted	Periodic maintenance and servicing; repairs contracted	Minimal costs to private industry or State

Table 9-1. QUALITATIVE COMPARISON OF STATE AND PRIVATE INDUSTRY (Continued)

Cost Categories and Considerations	State Participation	Private Industry	Total State Program Cost Implication
3.0 <u>Operation and Maintenance</u> (Continued)			
Inspection Facility Upkeep	Building maintenance and grounds upkeep probably contracted; utilities through local agencies; no property or income taxes	Building maintenance probably self-serviced; grounds upkeep probably contracted; utilities through local agencies; all property, employee, and income taxes	Moderate costs to private industry; minimal or negligible costs to State
Program Management and Administration	Use existing agency or create new agency; institute a nonprofit organization (e.g., U.S. Post Office, TVA)	Contract total effort to private company on a non-profit or fixed-fee basis	No cost to State if contracted to private company; moderate cost to State if State managed
Program Management and Administrative Personnel	Requires existing or new agency director, assistants, clerks, technical inspectors; requires existing or new regional director, assistants, clerks	Requires establishing separate department or subsidiary; utilize existing personnel or new hire	Moderate costs to private industry; probably minimal to moderate costs to State
Program Management and Administrative Office Space and Supplies	Requires existing or new agency offices; requires existing or new regional offices	Utilize existing HQ office; requires existing or new regional offices	Moderate costs to private industry; probably minimal to moderate costs to State

Table 9-1. QUALITATIVE COMPARISON OF STATE AND PRIVATE INDUSTRY (Continued)

Cost Categories and Considerations	State Participation	Private Industry	Total State Program Cost Implication
3.0 <u>Operation and Maintenance</u> (Continued)			
Program Management and Administration Administrative Functions	Maintain records, schedule vehicles, collect fees, review emission results, update standards and documentation, determine future requirements, evaluate newer equipments, determine budgetary requirements, and other program management functions; may involve many separate State agencies, new and/or existing	Similar management functions; may also involve many separate departments all within a single corporate structure	Moderate to high costs to private industry; moderate to high cost to State, depending on agencies and departments involved
Program Management and Administration Surveillance Program	Periodic certification of existing facilities; qualification/certification of new facilities	Privately operated facilities certified by State personnel	Minimal to moderate costs to State

Without exception, it was shown that option (1) with total State participation was the most cost-effective for each of the four test regimes. Option (2) was next, followed by option (3). The principal reason for this outcome can be attributed to the economies of a single agency versus distributed and diverse operations. Total private enterprise participation closely approximates total State participation with a few exceptions. Private industry is profit motivated, pays more taxes than the State, and, by necessity, would have as a parallel management structure the State agency responsible for program surveillance, resulting in duplicate costs to the overall program costs.

State licensing of privately owned inspection facilities would be the most costly since the advantages of large-scale purchasing are not present, and more facilities are required to accommodate the vehicle population due to licensed facilities performing functions other than inspection. This was based on the assumption that maximum utilization of inspection facilities cannot be guaranteed to justify single-purpose licensed facilities. Thus, other services must be provided by these facilities to supplement their income.

9.5 THE PEOPLE'S CHOICE

It was determined during the public opinion survey conducted by Opinion Research of California that 76.6 percent of 1000 interviewees believe that a mandatory vehicle emission inspection program is necessary. In addition, if a mandatory program is implemented, 82.1 percent would be in favor, 14.2 percent would be in opposition, and 3.7 percent have no opinion. Of the 1000 people contacted, 56.9 percent thought that the State of California should conduct the program, with 25 percent in favor of private garages and service stations. The remaining 18.1 percent did not know or care.

For those 569 who voted in favor of the State conducting the program, the five dominant reasons for selection were:

a. Have trust in; honest - 13.2 percent
b. Eliminate or cut down grafts, bribes - 13.2 percent
c. Do not trust private garages - 13.0 percent
d. Better enforcement - 10.9 percent
e. Private garages charge too much - 8.4 percent

Considering the 25 percent (250 to 1000) who favored private industry, the five dominant reasons for their selection were:

f. Convenience - 24 percent
g. Save taxpayers money, less cost to State - 12.4 percent
h. Support private enterprise - 11.6 percent
i. Less expensive, cheaper - 9.2 percent
j. Do a better job, generally - 8.8 percent

It is interesting to note that of the five dominant reasons for selecting the State to conduct the program, the first three involve trustworthiness of operating personnel. Those in favor of private industry cite convenience and money as their major reasons. There appears to be a paradox in the responses in that (e) indicates that people are in favor of a State-run program because private industry charges too much, while (i) shows that people are in favor of private industry because they are less expensive. Although the percentages are fairly even (8.4 to 9.2 percent), this is misleading. In actuality, the true quantity would be 8.4 percent of 569 versus 9.2 percent of 250. Thus, contrary to what the percentages indicate, the number of people who believe private industry charges too much exceeds those that believe it would be cheaper.

There were many other questions asked during the interviews. Section 7 summarized the pertinent findings, whereas Appendix K contains the detailed results. If one of the program goals is to satisfy the majority of the population, then perhaps Table 9-2 can be construed as a set of guidelines or requirements.

9.6 RECOMMENDED ARRANGEMENT

The results of the foregoing analysis indicate that the State of California should provide total program management, administration, and surveillance. In addition, it should have responsibility for the facility ownership and operation for the duration of the program. This was shown to be the most cost-effective combination for each of the four test regimes. Furthermore, it is the opinion of the public that this would be the most acceptable arrangement, if and when a mandatory program of vehicle emission inspection is implemented.

The service and repair of vehicles that do not meet inspection requirements should be performed by the private sector.

Table 9-2. CONSIDERATIONS FOR A STATEWIDE PROGRAM BASED ON PUBLIC OPINION SURVEY

Characteristics	Majority Opinion	Source* (Table No.)
Program Management	State of California	22
Inspection Facility	State operated	23
Inspection Interval	Once a year	25
Inspection Time Duration	15 minutes or less preferred, not greater than 45 minutes	29, 30, 31
Inspection Fees	\$1 or less preferred, no greater than \$3	33, 34, 35
Driving Distance to Facility	Not greater than 10 miles	38
Average Repair Costs	\$5 or less preferred, not greater than \$10	42, 43
Repair Time Allowed	15 days acceptable, 30 days preferred	63, 64
Enforcement Penalties	If necessary, would prefer monetary fines up to \$10	65, 66

*Appendix K, Results of Public Opinion Survey, Opinion Research of California

SECTION 10
CONCLUSIONS

This section identifies and summarizes the conclusions derived from the various tasks performed and described in the preceding sections.

10.1 INSTRUMENTATION SURVEY

Results of the instrumentation survey indicated the following:

- Equipment and technology are presently available to perform vehicle emission inspection for each of the test regimes.
- A statewide network of inspection facilities will necessitate minor modifications to these equipments.
- Additional effort will be required to integrate these various equipments into a workable and efficient system.
- Development effort will be required in the following areas:

  (1) Validation of O_2 as a reliable measurement of exhaust dilution

  (2) Prototype instruments for measurement and data recording systems.

10.2 FACILITY REQUIREMENTS

Results of the requirements analysis indicated that the following facilities would be required to implement a statewide network:

- Certificate of Compliance would require 1366 lanes, each capable of processing 30 vehicles per 8-hour day.
- Idle test would require 319 lanes, each capable of processing 127 vehicles per 8-hour day.
- Key-Mode test would require 398 lanes, each capable of processing 100 vehicles per 8-hour day.
- Diagnostic test would require 784 lanes, each capable of processing 52 vehicles per 8-hour day.

10.3 INSPECTION PERSONNEL REQUIREMENTS

Results of the personnel requirements analysis indicated the following:

- Each Certificate of Compliance test lane would require at least one technician. Training sessions would be approximately 116 hours per technician.
- Each Idle test lane would require two technicians, each with a different technical skill level. Total training required would be approximately 87 hours per technician.
- Each Key-Mode test lane would require two technicians, each with a different technical rating. Training period would be approximately 142 hours total per technician.
- Each Diagnostic test lane would require four technicians, comprised of two diagnosticians, and one each of lower technical ratings. Training requirements would amount to 174 hours per technician.

10.4 EFFECTIVENESS OF INSPECTION AND MAINTENANCE

Test regime effectiveness was measured in terms of emission reduction achieved as related to hydrocarbons, carbon monoxide, and oxides of nitrogen. It was shown that:

- All test regimes are effective in achieving emission reductions, but to different extents.
- Fifty percent of total emission reduction achieved will be realized from the South Coast Basin, Air Basin 1.
- Eighty percent of achievable effectiveness would be realized from the three largest basins, 92 percent from the five largest basins.
- Key-Mode is the most effective in achieving emission reductions during the first 5 to 7 years of program operation.
- Idle test is the next most effective inspection procedure and is essentially equal to Key-Mode after the first 5 to 7 years.
- Diagnostic test is relatively less effective than the previous two tests.
- Certificate of Compliance is relatively poor compared to the other three in terms of overall emission reduction for the total vehicle population.
- Service beyond the initial repair and adjustment should not be a requirement for vehicles failing emission inspection.

10.5 COST ANALYSIS

Results of the cost analysis for total program implementation revealed that:

- Least total cost would be a State managed program with State ownership and operation of inspection facilities.
- Second least costly would be a State regulated network of privately managed, owned, and operated new inspection facilities.
- Most costly would be a State managed program comprised of licensed, existing, inspection facilities privately owned and operated.
- Approximately 90 percent of total program cost is incurred by the five largest air basins.
- Emission inspection fees for each test regime would be as follows:

	Certificate of Compliance	Idle Test	Key-Mode Test	Diagnostic Test
State Owned, Operated	$2.31	$0.96	$1.05	$3.07
Private Owned, Operated	2.94	1.22	1.33	3.90
State Managed, Licensed	9.00	6.00	6.00	12.00

- Additional service and repair average costs exceed first or single service average cost. Average emission reduction achieved for additional service does not justify cost.
- Vehicle owner's service and repair average costs would be as follows:

Test Regime	All Service	First Service
Certificate of Compliance (including inspection fee)	$8.31	$7.88
Idle	$37.02	$27.19
Key-Mode	$28.24	$24.86
Diagnostic	$47.48	$33.29

- Cost-effective relative ranking of test regimes in terms of vehicle owner's repair cost per gram of emission reduction, listed in order of greatest merit, are Key-Mode, Idle, Diagnostic, Certificate of Compliance.

10.6 PUBLIC OPINION SURVEY

Results of the survey indicated the following:

- Three-fourths of vehicle owners believe a mandatory vehicle emission program is necessary.

- Primary advantages of inspection program as viewed by vehicle owners would be (1) reduction in air pollution, (2) force people to repair their cars, (3) detection of defective vehicles.

- Disadvantages of program would be expenses and inconvenience.

- More than half of those interviewed believe the program should be conducted by the State of California rather than private garages or service stations.

- Main reason for selecting the State to run the program was that people do not trust private garages or service stations.

- Main reason given for those selecting private industry was for the convenience factor.

- More than three-fourths of vehicle owners believe inspections should be required at least once a year.

- Majority of vehicle owners interviewed would continue to favor the program if the following conditions existed:

  (1) Inspection took 30 minutes or less
  (2) Inspection fee were $1.00 or less
  (3) Driving distance to inspection facility were 10 miles or less
  (4) Average repair costs were $10.00 or less.

- Acceptable length of time allowed to repair vehicle would be 15 days; majority would prefer 30 days.

10.7 COST-EFFECTIVENESS ANALYSIS

Results of the cost-effectiveness analysis indicate the following:

- State managed, owned, and operated inspection facilities are the most cost-effective, regardless of test regime implemented.

- State regulated, privately administered, owned, and operated newly constructed inspection facilities would rank second.

- State managed, privately owned and licensed, existing or modified facilities would be least cost-effective.

- Key-Mode is the most cost-effective among the test regimes considered during the first 5 to 7 years of total program life.

- Idle test is the next most cost-effective test regime, and is essentially as cost-effective as Key-Mode after the first 5 to 7 years of operation through program duration.

- Diagnostic test is less cost-effective than Idle but is more cost-effective than Certificate of Compliance.

10.8 STATE VERSUS PRIVATE INDUSTRY PROGRAM PARTICIPATION

The merits of State and private participation in a statewide inspection program were determined as follows:

- Cost analysis indicated that State management of inspection facilities, owned and operated by the State, would be the least costly.
- Cost-effectiveness analysis indicated that State managed, owned, and operated inspection facilities would be the most cost-effective.
- Public opinion survey established that the majority would prefer that the State manage and operate the inspection facilities.
- Least-cost program in terms of State finances would be privately owned and operated inspection facilities regulated and monitored by a State agency.

10.9 TEST REGIME COMPARISON MATRIX

Table 10-1 presents a summary analysis of the relative rankings of each of the four regimes with respect to various evaluation criteria. No attempt is made to weight one criterion over another, as such an effort would be purely subjective in nature. The relative ranking of each regime is presented for each criterion. An overall ranking of regimes is obtained by summing the individual criterion rankings. Key-Mode achieved the lowest score and was therefore ranked the best.

10.10 GENERAL RESULTS OF THE TECHNICAL AND ECONOMIC FEASIBILITY ANALYSES

The general results of the technical economic and public acceptability analysis were that:

- It is technically feasible to achieve vehicle emission reductions with each of the four test regimes.
- The total program implementation costs favor State managed, owned, and operated inspection facilities.
- The most cost-effective test regime is Key-Mode when considered over the first 5 to 7 years of operation.
- The closest competitor to Key-Mode is Idle test which is essentially equal to Key-Mode after the first 5 to 7 years and throughout the program duration.
- The most cost-effective arrangement would be to implement Key-Mode inspection facilities managed, owned, and operated by the State of California.
- The expected inspection fee per vehicle owner under this arrangement would be $1.05 annually.
- The expected repair cost for a failed vehicle would be $24.86.
- The typical annual fuel saving realized for a serviced vehicle would be $8.70.

Table 10-1. RELATIVE TEST REGIME RANKING WITH RESPECT TO EVALUATION CRITERIA

Criterion	Relative Ranking			
	Certificate of Compliance	Idle	Key-Mode	Diag-nostic
5 Year HC Reduction	4	2	1	3
5 Year CO Reduction	4	2	1	3
5 Year NO Reduction*	-	-	-	-
Retest Requirement	4	2	1	3
Applicability to Future Standards	4	3	1	1
Ability to Detect High Emitters	4	3	2	1
Least Likely to Commit Errors of Commission	4	3	2	1
Least Likely to Commit Errors of Omission	4	3	2	1
Dollar Cost per Gram Reduction	4	2	1	3
Inspection Fee	3	1	2	4
Vehicle Owner's Repair Cost	1	3	2	4
Estimated Fuel Savings Due to Reduction	4	2	1	3
Total Program Cost	3	1	2	4
Shortest Distance to Inspection Station	1	4	3	2
Time to Accomplish Inspection	4	1	2	3
Inspector Skill Level Requirement	3	1	1	4
Inspector Training Requirement	2	1	3	4
Test Equipment Availability	1	2	2	2
Totals	54	36	29	46
Overall Ranking	4	2	1	3

*Cars tested were 1970 and older and were not equipped with devices designed to reduce NO.

- The average driving distance for a vehicle owner would be 10 miles.
- Average inspection time is 4.8 minutes.
- Sixty-eight percent of those vehicles serviced will result in improved performance according to the owner's opinion; 21 percent of the owners will not no change or degradation in performance.
- Estimated dates in achieving the 1940 total vehicle emission level as a function of implementing periodic vehicle emission inspection are as follows:

	Combined HC, CO, NO_x	HC Only	CO Only	NO_x Only
Without Inspection	1987	1975	1991*	1990
With Key Mode or Idle	1982	1972	1984	1991*

*Not achieved within time-frame considered.

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